# Final Program and Abstracts

## SIAM Conference on Applications of Dynamical Systems

MAY 27 - 31, 2003
SNOWBIRD SKI & SUMMER RESORT
SNOWBIRD, UT

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Sponsored by SIAM Activity Group on Dynamical Systems

The SIAM Activity Group on Dynamical Systems provides a forum for the exchange of ideas and information between mathematicians and applied scientists whose work involves dynamical systems. The goal of this group is to facilitate the development and application of new theory and methods of dynamical systems. The techniques in this area are making major contributions in many areas, including biology, nonlinear optics, fluids, chemistry, and mechanics. This activity group sponsors special sessions at SIAM meetings and conferences, organizes a biennial conference, and has an electronic newsletter.



**Society for Industrial and Applied Mathematics**
**3600 University City Science Center**
**Philadelphia, PA 19104-2688**
**Telephone: 215-382-9800 Fax: 215-386-7999**
**Conference E-mail:** ***meetings@siam.org***
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siam Society for Industrial and Applied Mathematics

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## Organizing Committee

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## E-Mail Room Hours of Operation

Monday 5/26 ......... 1:00 p.m.- 9:00 p.m.

Tuesday 5/27 ......... 7:00 a.m.- 9:00 p.m.

Wednesday 5/28 .... 7:00 a.m.- 9:00 p.m.

Thursday 5/29 ....... 7:00 a.m. - 9:00 p.m.

Friday 5/30 ........... 7:00 a.m. - 9:00 p.m.

Saturday 5/31 ........ 7:00 a.m.- 3:00 p.m.

# General Information

## Memorial Day Celebration!

Please join us at our Welcome Reception Barbecue, Monday, May 26th from 6-8 PM, where we will be serving traditional barbecue fare including hot dogs, hamburgers, veggieburgers, assorted salads, beans, snacks, dessert and beverages!

## SIAM Registration Desk

The SIAM registration desk is located in the Ballroom Lobby and is open during the following times:

| | |
|---|---|
| Monday May 26 (Memorial Day) | 4:00 PM - 7:00 PM |
| Tuesday May 27 | 7:30 AM - 4:30 PM |
| Wednesday May 28 | 8:00 AM - 4:30 PM |
| Thursday May 29 | 8:00 AM - 4:30 PM |
| Friday May 30 | 8:00 AM - 4:30 PM |
| Saturday May 31 | 8:00 AM - 4:30 PM |

## Hotel Address

Snowbird Ski and Summer Resort
Highway 210, Little Cottonwood Canyon
Snowbird, UT 84092

## Hotel Telephone Number

The telephone number is 1-801-742-2222. The hotel operator can either connect a caller with the SIAM registration desk for a message to be taken and posted to the SIAM message board or forward a caller to an attendee's room to leave a message.

## Transportation to-and-from Airport

Canyon Transportation is a shuttle service that transports passengers between the SLC airport and Snowbird. RESERVATIONS MUST BE MADE IN ADVANCE, 24 hours prior to your scheduled departure. You may do this by calling Canyon directly at 1-800-255-1841. When calling to make reservations, be sure to have the name of the airline you are using, the flight number and scheduled departure time.

## Fitness Center

SIAM attendees may use the Cliff Spa for $5 a day.

## Corporate Members and Sponsor

SIAM corporate members provide their employees with knowledge about, access to, and contacts in the applied mathematics and computational sciences community through their membership benefits. Corporate membership is more than just a bundle of tangible products and services; it is an expression of support for SIAM and its programs. SIAM is pleased to acknowledge its corporate members. In recognition of their support, non-member attendees who are employed by the following organizations are entitled to the SIAM member registration rate.

## Corporate Sponsor

Coastcom

## Corporate Members

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The Boeing Company
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MSC. Software Corporation
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National Security Agency
NEC Research Institute
Oak Ridge National Laboratory, managed by the Lockheed Martin Energy Research Corporation for the Department of Energy

# DS03 Program-At-A-Glance

SIAM
CONFERENCE
ON APPLICATIONS
OF DYNAMICAL
SYSTEMS

MAY 27 - 31, 2003
SNOWBIRD SKI & SUMMER RESORT
SNOWBIRD, UT

# DS03 Program-at-a-Glance

## Monday May 26

**4:00 PM - 7:00 PM**
Registration
*Ballroom Lobby*

**1:00 PM - 9:00 PM**
E-Mail
*Red Pine*

**6:00 PM - 8:00 PM**
Welcome Reception BBQ
*Outdoors*

**UNDER CONSTRUCTION:**

This program is subject to change. Check the "Program Updates" posted on the bulletin board located in the registration area. Changes are posted once daily, prior to the opening session.

## Tuesday May 27

**7:00 AM - 9:00 PM**
E-Mail
*Red Pine*

**7:30 AM - 4:30 PM**
Registration
*Ballroom Lobby*

**8:15 AM - 8:30 AM**
Announcements
*Ballroom II*

**8:30 AM - 10:30 AM**
**Concurrent Sessions**
**MS1** *Ballroom I*
**MS2** *Ballroom II*
**MS3** *Ballroom III*
**MS4** *Magpie A*
**MS5** *Magpie B*
**MS6** *Wasatch A*
**MS7** *Wasatch B*
**MS8** *Maybird*
**MS9** *Superior A*
**MS10** *Superior B*
**MS11** *White Pine*
**MS12** *Eagles Nest*

**10:30 AM - 11:00 AM**
Coffee Break
*Golden Cliff*

**11:00 AM - 12:00 PM**
**IP1** The Navier-Stokes Equations with Moving Interfaces and Surface Tension
Steve Shkoller, University of California, Davis
*Ballroom*

**12:00 PM - 1:30 PM**
Lunch Break
*Attendees on their own*

**12:00 PM - 12:00 AM**
Game Room
*Eagles Nest*

**1:30 PM - 2:30 PM**
**IP2** Sonoluminescence: Illuminating Bubbles
Detlef Lohse, University of Twente, Netherlands
*Ballroom*

**2:30 PM - 2:45 PM**
Intermission

**2:45 PM - 3:45 PM**
**Concurrent Sessions**
**CP1** *Ballroom I*
**CP2** *Ballroom II*
**CP3** *Ballroom III*
**CP4** *Magpie A*
**CP5** *Magpie B*
**CP6** *Wasatch A*
**CP7** *Wasatch B*
**CP8** *Maybird*
**CP9** *Superior A*
**CP10** *Superior B*
**CP11** *White Pine*

**3:45 PM - 4:15 PM**
Coffee Break
*Golden Cliff*

## Tuesday & Wednesday May 27 & 28

**4:15 PM - 6:15 PM**
**MS13** *Ballroom I*

**4:15 PM - 6:45 PM**
**Concurrent Sessions**
**MS14** *Ballroom II*
**MS15** *Ballroom III*

**4:15 PM - 7:15 PM**
**Concurrent Sessions**
**MS16** *Magpie A*
**MS17** *Magpie B*
**MS18** *Wasatch A*
**MS19** *Wasatch B*
**MS20** *Maybird*
**MS21** *Superior A*
**MS22** *Superior B*
**MS23** *White Pine*

**7:15 PM - 8:30 PM**
Dinner Break
*Attendees on their own*

**8:30 PM - 9:00 PM**
The SIAM Activity Group on Dynamical Systems Prize Session
The Jürgen Moser Lecture and the J.D. Crawford Prize
*Ballroom*

**8:45 PM - 9:30 PM**
The Jürgen Moser Lecture: Is There a Natural Dynamics for Systems with Many Degrees of Freedom?
David Ruelle, Institut des Hautes Etudes Scientifiques, France
*Ballroom*

## Wednesday, May 28

**7:00 AM - 9:00 PM**
E-Mail
*Red Pine*

**8:00 AM - 4:30 PM**
Registration
*Ballroom Lobby*

**8:00 AM - 12:00 AM**
Game Room
*Eagles Nest*

**8:15 AM - 8:30 AM**
Announcements
*Ballroom II*

**8:30 AM - 10:30 AM**
**Concurrent Sessions**
**MS24** *Superior B*
**MS25** *Ballroom III*
**MS26** *Wasatch B*
**MS27** *Ballroom II*
**MS28** *Ballroom I*
**MS29** *Magpie A*
**MS30** *Wasatch A*
**MS31** *Magpie*
**MS32** *Maybird*
**MS33** *Superior A*
**MS34** *White Pine*

**10:30 AM - 11:00 AM**
Coffee Break
*Golden Cliff*

# DS03 Program-at-a-Glance

## Wednesday May 28

**11:00 AM - 12:00 PM**
**IP3** What is the Design Trick by Which Natural Selection Evolved Such Astonishingly Robust Genetic Networks?
Garrett Odell, University of Washington
*Ballroom*

**12:00 PM - 1:30 PM**
Lunch Break
*Attendees on their own*

**1:30 PM - 2:30 PM**
**IP4** Equation-Free Multiscale Computation: Enabling Microscopic Simulators to Perform System-Level Tasks
Yannis Kevrekidis, Princeton University
*Ballroom*

**2:30 PM - 2:45 PM**
Intermission

**2:45 PM - 3:45 PM**
**Concurrent Sessions**
**CP12** *Ballroom I*
**CP13** *Ballroom II*
**CP14** *Ballroom III*
**CP15** *Magpie A*
**CP16** *Magpie B*
**CP17** *Wasatch A*
**CP18** *Wasatch B*
**CP19** *Maybird*
**CP20** *Superior A*
**CP21** *Superior B*

**2:45 PM - 4:05 PM**
**CP22** *White Pine*

**3:45 PM - 4:15 PM**
Coffee Break
*Golden Cliff*

**4:15 PM - 6:45 PM**
**Concurrent Sessions**
**MS35** *Superior A*
**MS37** *Ballroom II*

### Key to abbreviations and symbols

CP = Contributed Presentations

IP = Invited Plenary Presentations

MS = Minisymposium

= Coffee breaks

= Lunch breaks

= Poster Session

## Wednesday & Thursday May 28 & 29

**4:15 PM - 7:15 PM**
**Concurrent Sessions**
**MS36** *Ballroom I*
**MS38** *Ballroom III*
**MS39** *Magpie A*
**MS40** *Magpie B*
**MS41** *Wasatch A*
**MS42** *Maybird*
**MS43** *Superior B*
**MS44** *Wasatch B*
**MS45** *White Pine*

**7:15 PM - 8:30 PM**
Dinner Break
*Attendees on their own*

**8:30 PM - 9:30 PM**
SIAG/DS Business Meeting
*Ballroom II*

## Thursday, May 29

**7:00 AM - 9:00 PM**
E-Mail
*Red Pine*

**8:00 AM - 4:30 PM**
Registration
*Ballroom Lobby*

**8:00 AM - 12:00 AM**
Game Room
*Eagles Nest*

**8:15 AM - 8:30 AM**
Announcements
*Ballroom II*

**8:30 AM - 10:30 AM**
**Concurrent Sessions**
**MS46** *Ballroom I*
**MS47** *Ballroom II*
**MS48** *Ballroom III*
**MS49** *Magpie A*
**MS50** *Magpie B*
**MS51** *Wasatch A*
**MS52** *Superior A*
**MS53** *Superior B*
**MS54** *Maybird*
**MS55** *White Pine*
**MS56** *Wastach B*

**10:30 AM - 11:00 AM**
Coffee Break
*Golden Cliff*

**11:00 AM - 12:00 PM**
**IP5** Schooling by Design: Coordinated Multi-Vehicle Dynamics
Naomi Ehrich Leonard, Princeton University
*Ballroom*

**12:00 PM - 1:30 PM**
Lunch Break
*Attendees on their own*

## Thursday May 29

**1:30 PM - 2:30 PM**
**IP6** Dynamical Systems and the Navier-Stokes Equations
Gene Wayne, Boston University
*Ballroom*

**2:30 PM - 2:45 PM**
Intermission

**2:45 PM - 3:45 PM**
**Concurrent Sessions**
**CP23** *Ballroom I*
**CP24** *Magpie B*
**CP25** *Ballroom II*
**CP26** *Ballroom III*
**CP27** *White Pine*
**CP28** *Wasatch A--CANCELLED*
**CP29** *Magpie A*
**CP30** *Wasatch B*
**CP31** *Maybird*
**CP32** *Superior A*
**CP33** *Superior B*

**3:45 PM - 4:15 PM**
Coffee Break
*Golden Cliff*

**4:15 PM - 7:15 PM**
**Concurrent Sessions**
**MS57** *Magpie A*
**MS58** *Magpie B*
**MS59** *Ballroom I*
**MS60** *Wasatch A*
**MS61** *Wasatch B*
**MS62** *Ballroom III*
**MS63** *Ballroom II*
**MS64** *Superior A*
**MS65** *Superior B*
**MS66** *Maybird*
**MS67** *White Pine*

**7:15 PM - 8:30 PM**
Dinner Break
*Attendees on their own*

**8:30 PM - 10:00 PM**
PP1 Poster Session
*Ballroom and Foyer*

| Friday May 30 | Friday & Saturday May 30 & 31 | Saturday May 31 |
|---|---|---|

**7:00 AM - 9:00 PM**
E-Mail
*Red Pine*

**8:00 AM - 4:30 PM**
Registration
*Ballroom Lobby*

**8:00 AM - 12:00 AM**
Game Room
*Eagles Nest*

**8:15 AM - 8:30 AM**
Announcements
*Ballroom II*

**8:30 AM - 10:30 AM**
**Concurrent Sessions**
**MS68** *Ballroom I*
**MS69** *Magpie A*
**MS70** *Ballroom III*
**MS71** *Magpie B*
**MS72** *Wasatch A*
**MS73** *Ballroom II*
**MS74** *Wasatch B*
**MS75** *Maybird*
**MS76** *Superiour B*
**MS77** *Superior A*
**MS78** *White Pine*

**10:30 AM - 11:00 AM**
Coffee Break
*Golden Cliff*

**11:00 AM - 12:00 PM**
**IP7** Dynamic Features of Motor Networks and Behavior in Parkinson's Disease
Karen A. Sigvardt, University of California, Davis
*Ballroom*

**12:00 PM - 1:30 PM**
Lunch Break
*Attendees on their own*

**1:30 PM - 2:30 PM**
**IP8** Computer Simulation of Dynamical Systems: The Good, the Bad, and the Awful
Leo Kadanoff, University of Chicago
*Ballroom*

**2:30 PM - 2:45 PM**
Intermission

**2:45 PM - 3:45 PM**
**Concurrent Sessions**
**CP34** *Ballroom I*
**CP35** *Ballroom II*
**CP36** *Ballroom III*
**CP37** *Superior A*
**CP38** *Superior B*
**CP39** *Maybird*
**CP40** *White Pine*
**CP41** *Magpie A*
**CP42** *Magpie B*
**CP43** *Wasatch A*
**CP44** *Wasatch B*

**3:45 PM - 4:15 PM**
Coffee Break
*Golden Cliff*

**4:15 PM - 6:45 PM**
**Concurrent Sessions**
**MS79** *Ballroom II*
**MS80** *Magpie A*

**4:15 PM - 7:15 PM**
**Concurrent Sessions**
**MS81** *Magpie B*
**MS82** *Ballroom I*
**MS83** *Ballroom III*
**MS84** *Wasatch A*
**MS85** *Wasatch B*
**MS86** *Maybird*
**MS87** *White Pine*
**MS88** *Superior A*
**MS89** *Superior B*

## Saturday, May 31

**7:00 AM - 3:00 PM**
E-Mail (closes at 3:00 PM)
*Red Pine*

**8:00 AM - 9:00 PM**
Game Room
*Eagles Nest*

**8:00 AM - 4:30 PM**
Registration
*Ballroom Lobby*

**8:15 AM - 8:30 AM**
Announcements
*Ballroom II*

**8:30 AM - 10:30 AM**
**Concurrent Sessions**
**MS90** *Ballroom I*
**MS91** *Magpie A*
**MS92** *Magpie B*
**MS93** *Ballroom II*
**MS94** *Ballroom III*
**MS95** *Wasatch A*
**MS96** *Wasatch B*
**MS97** *White Pine*
**MS98** *Maybird*
**MS99** *Superior A*
**MS100** *Superior B*

**10:30 AM - 11:00 AM**
Coffee Break
*Golden Cliff*

**11:00 AM - 12:00 PM**
**IP9** Electro-Manipulation of Particles in Fluidic Devices
Nadine Aubry, New Jersey Institute of Technology
*Ballroom*

**12:00 PM - 1:30 PM**
Lunch Break
*Attendees on their own*

**1:30 PM - 2:30 PM**
**IP10** Singular Asymptotics for Nonlinear Dispersive Waves
Peter D. Miller, University of Michigan, Ann Arbor
*Ballroom*

**2:30 PM - 2:45 PM**
Intermission

**2:45 PM - 3:45 PM**
**Concurrent Sessions**
**CP45** *Ballroom I*
**CP46** *Ballroom II*
**CP47** *Ballroom III*
**CP48** *Superior A*
**CP49** *Superior B*
**CP50** *Wasatch A*
**CP51** *Wasatch B*
**CP52** *Magpie A*
**CP53** *Magpie B*
**CP54** *White Pine*

**3:45 PM - 4:15 PM**
Coffee Break
*Golden Cliff*

**4:15 PM - 6:15 PM**
**MS101** *Maybird*

**4:15 PM - 6:45 PM**
**Concurrent Sessions**
**MS102** *Ballroom II*
**MS103** *Superior B*
**MS104** *Ballroom III*

**4:15 PM - 7:15 PM**
**Concurrent Sessions**
**MS105** *Magpie A*
**MS106** *Magpie B*
**MS107** *Wasatch A*
**MS108** *Wasatch B*
**MS109** *Superior A*

**4:15 PM - 7:45 PM**
**MS110** *White Pine*
**MS111** *Ballroom I*

**7:45 PM**
Conference Adjourns

# DS03 Program-At-A-Glance

# OPEN HERE

# General Information, cont.

## Corporate Members , *cont.*

Pacific Northwest National Laboratory, operated for the Department of Energy by Battelle

Palo Alto Research Center

Phillips Research

Schlumberger-Doll Research

Telcordia Technologies

**List current at time of printing.*

## Funding Agency

SIAM and the Conference Organizing Committee wish to extend their thanks and appreciation to the Army Research Office and the Office of Naval Research for their support of this conference.

## Join SIAM - The Premier Professional Society for Applied Mathematicians and Computational Scientists

SIAM members save $90 on registration for the 2003 SIAM Conference on Applications of Dynamical Systems! In addition to supporting the profession, SIAM members receive subscriptions to *SIAM Review* and *SIAM News*, and enjoy substantial discounts on SIAM books, journal subscriptions and conference registrations.

Join SIAM now and enjoy a 12-month membership (from January 1, 2003 through December 31, 2003) for just $108. If you've already paid the non-member registration fee for the 2003 SIAM Conference on Applications of Dynamical Systems, we'll deduct the $90 member discount from your dues -- you will only pay $18 for 12 months of membership.

Complimentary Graduate Student Memberships are available to all graduate students (Master's and Ph.D. candidates) who attend an institution that is an Academic Member of SIAM (http://www.siam.org/membership/acadlist.htm).

Visit the Membership Counter in the registration area during the conference, join online or download an application at http://www.siam.org/membership/applications.htm, or contact SIAM Customer Service.

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Fax: 215-386-7999

E-mail: service@siam.org

Postal mail: SIAM, 3600 University City Science Center, Philadelphia, PA 19104-2688

## SIAM Audio-visual Policy

**Standard AV Set-Up in Meeting Rooms**

Each plenary session room will have two overhead projectors and two screens, and a data projector. All other breakout rooms will have one overhead projector, one screen, and a data projector.

SIAM is unable to order computers for any speakers. If Power Point or another type of presentation utilizing computer is planned, the speaker must bring his/her own computer.

If you have questions regarding availability of equipment in the meeting room of your presentation, please see a SIAM staff member at the registration desk.

## Hotel Check-in and Check-out Times

Check-in time is 4:00 PM.

Check-out time is 11:00 AM.

## E-mail Access

There will be e-mail access available in the Internet Café, located in the Red Pine room. Due to high demand, please limit the time you spend on-line.

## Registration Fee Includes:

- Welcome Reception Barbeque
- Two Coffee Breaks
- Admission to all Technical Sessions
- Admission to Business Meeting
- Admission to Poster Session and Dessert Reception
- Room set-ups and audio-visual equipment
- Use of Internet Café

## Fitness Center

SIAM Attendees may use the Cliff Spa for $5.00 a day during your stay.

## Eating Options

A Grab and Go Kiosk will be open for breakfast (6:30 AM -8:30 AM) and lunch (12:00 PM-1:30 PM). The kiosk will offer the following choices:

| | |
|---|---|
| Bagel w/cream cheese | $3.00 |
| Danish | $2.50 |
| Coffee | $1.50 |
| Juice (16 oz. bottle) | $2.75 |
| Sandwich & Chips | $7.00 |
| Baked Potato w/chili | $7.00 |
| Soft Drinks | $2.00 |
| Cookies/Brownies | $1.50 |
| Assorted Fruit | $1.00 |

Other eating option are also available; five restaurants and three lounges are located at Snowbird.

## Job Postings

There is a dedicated bulletin board located in the registration area for job postings. Academic and corporate employers who wish to solicit applications or interview during the conference should post information here. Attendees who wish to review job opportunities should check this board.

## Important Notice to Poster Presenters

Poster presenters are requested to set up their poster material in the Ballroom and Foyer. Presenters may set up their posters on Thursday, May 29 between the hours of 8:00 PM and 8:30 PM. All materials must be posted by 8:30 PM, the official start time of the session. Poster displays must be removed by 10:30 PM, immediately following the end of the poster session. Posters remaining after this time will be discarded. SIAM is not responsible for discarded posters.

## Get-togethers

Welcome Reception Barbeque

Monday, May 26th, 6:00 PM - 8:00 PM

Poster Session

Thursday, May 29th, 8:30 PM - 10:00 PM

Business Meeting

Wednesday, May 28th, 8:30 PM

# Invited Plenary Presentations

## Tuesday, May 27

11:00 AM - 12:00 PM

IP1 The Navier-Stokes Equations with Moving Interfaces and Surface Tension

Steve Shkoller, *University of California, Davis*

1:30 PM - 2:30 PM

IP2 Sonoluminescence: Illuminating Bubbles

Detlef Lohse, *University of Twente, Netherlands*

8:45 PM - 9:30 PM

The Jürgen Moser Lecture: Is There a Natural Dymanics for Systems with Many Degrees of Freedom?

David Ruelle, *Institut des Hautes Etudes Scientifiques, France*

## Wednesday, May 28

11:00 AM - 12:00 PM

IP3 What is the Design Trick by Which Natural Selection Evolved Such Astonishingly Robust Genetic Networks?

Garrett Odell, *University of Washington*

1:30 PM - 2:30 PM

IP4 Equation-Free Multiscale Computation: Enabling Microscopic Simulators to PerformSystem-Level Tasks

Yannis Kevrekidis, *Princeton University*

## Thursday, May 29

11:00 AM - 12:00 PM

IP5 Schooling by Design: Coordinated Multi-Vehicle Dynamics

Naomi Ehrich Leonard, *Princeton University*

1:30 PM - 2:30 PM

IP6 Dynamical Systems and the Navier-Stokes Equations

Gene Wayne, *Boston University*

## Invited Plenary Presentations

### Friday, May 30

11:00 AM - 12:00 PM

IP7 Dynamic Features of Motor Networks and Behavior in Parkinson's Disease

Karen A. Sigvardt, *University of California, Davis*

1:30 PM - 2:30 PM

IP8 Computer Simulation of Dynamical Systems: The Good, the Bad, and the Awful

Leo Kadanoff, *University of Chicago*

### Saturday, May 31

11:00 AM - 12:00 PM

IP9 Electro-Manipulation of Particles in Fluidic Devices

Nadine Aubry, *New Jersey Institute of Technology*

1:30 PM - 2:30 PM

IP10 Singular Asymptotics for Nonlinear Dispersive Waves

Peter D. Miller, *University of Michigan, Ann Arbor*

**All Invited Plenary presentations will be given in the Ballroom.**

# FINAL PROGRAM

## SIAM CONFERENCE ON APPLICATIONS OF DYNAMICAL SYSTEMS

MAY 27 - 31, 2003
SNOWBIRD SKI & SUMMER RESORT
SNOWBIRD, UT

# Monday, May 26

## Registration
*4:00 PM-7:00 PM*
*Room: Ballroom Lobby*

## Welcome Reception BBQ
*6:00 PM-8:00 PM*
*Room: Outdoors*

# Tuesday, May 27

## Registration
*7:30 AM-4:30 PM*
*Room: Ballroom Lobby*

## Announcements
*8:15 AM-8:30 PM*
*Room: Ballroom II*

## MS1 (For Part II, see MS 28)

### Phase Synchronization of Chaotic Systems: Theory and Applications
*8:30 AM-10:30 AM*
*Room: Ballroom I*

Phase synchronization (PS) of chaotic systems has attracted a wide interest in the scientific community. This minisymposium reports on recent advancements in the theoretical understanding of the role of noise in inducing phase synchronized states, and presents several experimental examples of PS in plasma physics, in fluid dynamics and in nonlinear optics.

**Organizer: Stefano Boccaletti**
*Istituto Nazionale di Ottica Applicata, Italy*

**Organizer: Epaminonda Rosa, Jr.**
*Illinois State University*

**8:30-8:55 Experimental Characterization of the Transition to Phase Synchronization in Homoclinic Chaos**
Riccardo Meucci, F. Tito Arecchi, Enrico Allaria, and *Stefano Boccaletti*, Istituto Nazionale di Ottica Applicata, Italy

**9:00-9:25 Phase Synchronization of Plasma Dynamics**
*Epaminonda Rosa, Jr.*, Illinois State University; Catalin M. Ticos, University of Oxford, United Kingdom; and Juergen Kurths, Universität Potsdam, Germany

**9:30-9:55 Phase Synchronization of Laser Dynamics**
Rajarshi Roy, University of Maryland, College Park

**10:00-10:25 Control and Synchronization of Homoclinic Chaos and its Implication for Neurodynamics**
F. Tito Arecchi, Istituto Nazionale di Ottica Applicata, Italy

Tuesday, May 27

## MS2

### Nonlinear Dynamics in Crystal Growth Processes
*8:30 AM-10:30 AM*
*Room: Ballroom II*

Various modern crystal growth processes on which electronics industry is based on exhibit rich nonlinear dynamics. This minisymposium will cover wide spectrum of nonlinear phenomena in crystal growth, like morphological instabilities in epitaxial solid films, phase-field models, grain boundary motion, faceting of thermodynamically unstable surfaces, monte-carlo simulations, instabilities in step-flow growth, electrodeposition, and other important phenomena.

**Organizer: Alexander A. Golovin**
*Northwestern University*

**8:30-8:55 Convective Instability During Step-Flow Epitaxial Growth**
Andrew Zangwill and *Michael F. Schatz*, Georgia Institute of Technology; Navot Israeli, University of Illinois, Urbana-Champaign; and Daniel Kandel, Weizmann Institute of Science, Israel

**9:00-9:25 Models for Selective Area Epitaxy**
Michael Mauk, AstroPower, Inc.; and Richard Braun and *Michael Khenner*, University of Delaware

**9:30-9:55 Some New Tools for Simulating Epitaxial Growth**
Tim Schulze, University of Tennessee

**10:00-10:25 Morphological Instabilities and Additive-Induced Stabilization During Electrodeposition**
Andrew Bocarsly, David Srolovitz, and *Mikko Haataja*, Princeton University

Tuesday, May 27

# MS3

## Bursting in Mappings

*8:30 AM-10:30 AM*

*Room: Ballroom III*

When a system's activity alternates between a resting state (e.g., an equilibrium) and an active state (e.g., periodic activity) the system is said to exhibit bursting behavior. Networks of bursting neurons can exhibit interesting collective behavior that can rarely be seen in networks of periodic oscillators. This mini-symposium is devoted to a recently emerged field --- bursting dynamics of mappings, such as the fast/slow system $x_{n+1} = f(x_n,y_n)$ \\ $y_{n+1} = y_n + eg(x_n)$ Considering maps instead of ODEs provides a number of theoretical and computational advantages. In particular, one can explore collective behavior of millions of coupled discrete-time bursters using a desktop PC.

**Organizer: Eugene M. Izhikevich**
*The Neurosciences Institute*

**Organizer: Andrey Shilnikov**
*Georgia State University*

### 8:30-8:55 Classification of Bursting in Mappings

Eugene M. Izhikevich, The Neurosciences Institute

### 9:00-9:25 Modeling of Spiking-Bursting Neural Behavior Using Two-Dimensional Maps

Nikolai Rulkov, University of California, San Diego

### 9:30-9:55 Bursting as an Emergent Phenomenon in Coupled Maps

Gerda de Vries, University of Alberta, Canada

### 10:00-10:25 Canards and Chaos in Some Slow-fast Maps

Andrey Shilnikov, Georgia State University

Tuesday, May 27

# MS4

## Dynamics of Nonlinear Systems with Memory

*8:30 AM-10:30 AM*

*Room: Magpie A*

This minisymposium will review the recent progress in the dynamics of nonlinear systems with memory. Interesting memory-induced phenomena occur in both small systems with time-delayed feedback as well as in large spatiotemporal systems and distributed networks of coupled agents. This research is motivated by problems of physics,engineering, neurobiology, economics, and sociology. The speakers in this minisymposium will address theoretical and experimental developments in chaotic delay-differential equations, stochastic resonance inbistable systems with delay, memory-related phenomena in neurodynamics, etc.

**Organizer: Lev S. Tsimring**
*University of California, San Diego*

**Organizer: Arkady Pikovsky**
*University of Potsdam, Germany*

### 8:30-8:55 Noise-induced Dynamics in Bistable Systems with Delay

*Lev S. Tsimring*, University of California, San Diego; and Arkady Pikovsky, University of Potsdam, Germany

### 9:00-9:25 Effect of Time Delayed Feedback on Coherence Properties of Chaotic and Noisy Oscillators

Denis Goldobin, Perm University, Russia; and Michael Rosenblum and *Arkady Pikovsky*, University of Potsdam, Germany

### 9:30-9:55 Correlated Firing and Delayed Feedback Memory Effects in Neurons

Rob Morse, University of Keele. United Kingdom; and Benjamin Lindner, Jason W. Middleton, Maurice J. Chacron, and *Andre Longtin*, University of Ottawa, Canada

### 10:00-10:25 Fast Control using Delayed Feedback

*John Milton*, University of Chicago Hospitals; and Juan Luis Cabrera, Instituto Venezolano de Investigaciones Cientificas, Venezuela

Tuesday, May 27

# MS5

## Elastic Growth and Morphogenesis: Theory and Applications

*8:30 AM-10:30 AM*

*Room: Magpie B*

One of the most fascinating aspects of living organisms is their ability to grow and develop shapes transforming the information at the cellular level to functional organisms. In many instances, growth occurring in the bulk of a tissue may be model as a growing elastic structure. A complete mathematical formulation and thorough understanding of elastic growth is still lacking despite some recent advances in the field. This mini-symposium will address both theoretical issues and present some specific applications of elastic growth in filaments, membranes, crystal, and bulk tissues.

**Organizer: Michael Tabor**
*University of Arizona*

**Organizer: Alain Goriely**
*University of Arizona*

### 8:30-8:55 Growth and Form of Filamentary Micro-organisms

Michael Tabor, University of Arizona

### 9:00-9:25 Growth Induced Instabilities in Elastic Materials

*Martine Ben Amar*, Laboratoire de Physique Statistique, Ecole Normale Superieure, France; and Alain Goriely, University of Arizona

### 9:30-9:55 Supercoiling Dynamics of Growing Filaments

*Thomas R. Powers*, Brown University; C W. Wolgemuth, University of Connecticut Health Center; and Raymond E. Goldstein, University of Arizona

### 10:00-10:25 Surface Stress and Growing Elastic Bodies

Stephen J. Watson, Northwestern University

Tuesday, May 27

## MS6 (For Part II, see MS 30)

### Scientific Simulation Using Python

*8:30 AM-10:30 AM*

*Room: Wasatch A*

Exploration of the behavior of complex dynamical systems such as the climate system, large chemical reaction networks, or collections of interacting molecules requires a flexible modeling environment. The traditionalprogramming archetype of compiled source code (particularly Fortran) does not offer the re-usability, modularity and interactivity required by the task. There is increasing interest in Python (a high level interpreted object-oriented programming language) as a glue for steering computationally intensive scientific simulation. This is made possible by the availability of mature tools for turning compiled high performance subroutines into Python commands. Python also offers the advantage of being intuitive and easy to learn. This symposium showcases the use of Python in a variety of scientific simulations.

**Organizer: Raymond T. Pierrehumbert**
*University of Chicago*

**8:30-8:55 Python for Climate Modelling**
Raymond T. Pierrehumbert, University of Chicago

**9:00-9:25 A Python Based Computational Environment for the Dynamical Systems Analysis of Transport in Geophysical Flows**
Des Small and *Steve Wiggins*, University of Bristol, United Kingdom

**9:30-9:55 Run-time Integration of Nonconforming Finite Elements and Visualization via Scripting**
A.N.M. Imroz Choudhury and *Robert C. Kirby*, University of Chicago

**10:00-10:25 Use of Python for Normal Form Analysis in Phase Space Transition State Theory**
Stephen Wiggins and *Andrew Burbanks*, University of Bristol, United Kingdom

Tuesday, May 27

## MS7 (For Part II, see MS 26)

### Non-integrable Hamiltonians - Analysis and Applications

*8:30 AM-10:30 AM*

*Room: Wasatch B*

Arising in a variety of physical and mechanical systems, non-integrable Hamiltonian flows admit complicated types of solutions, with characteristics that are not well understood even for low dimensional systems. Analyzing the behavior of invariant manifolds, structure of resonances, and bifurcations in the near-integrable limit shed light on different aspects of the dynamics. On the other hand, understanding the properties of nominal dynamics allows devising perturbations that serve as efficient methods to control original systems. Applications of these results are important in such diverse fields as satellites' motion, plasma physics and fluid mixing.

**Organizer: Vered Rom-Kedar**
*The Weizmann Institute*

**Organizer: Dmitri L. Vainchtein**
*University of California, Santa Barbara*

**8:30-8:55 Putting Resonances at Work: Resonance Phenomena and Control**
Igor Mezic and *Dmitri L. Vainchtein*, University of California, Santa Barbara

**9:00-9:25 On Resonances and Energy Surfaces**
Anna Litvak-Hinenzon, University of Warwick, United Kingdom; and *Vered Rom-Kedar*, The Weizmann Institute

**9:30-9:55 Almost Collision Solutions of the 3 Body Problem**
Robert MacKay, University of Warwick, United Kingdom; and *Sergey Bolotin*, University of Wisconsin, Madison

**10:00-10:25 Persistence of Heteroclinic Orbits for Billiards and Twist Maps**
Sergey Bolotin, University of Wisconsin, Madison; and Rafael Ramirez-Ros and *Amadeu Delshams*, Universitat Politecnica de Catalunya, Spain

Tuesday, May 27

## MS8

### Invariant Manifolds and Applications

*8:30 AM-10:30 AM*

*Room: Maybird*

The focus of this minisymposium is on invariant manifold based reduction techniques and their applications. Such reduction techniques continue to provide deep insights into a variety of problems in synchronization, bursting behavior and control theory. In addition, new techniques are still being sought to more efficiently and effectively approximate invariant manifolds, along with rigorous error estimates. The speakers will present recent discoveries in applications of invariant manifolds mentioned above, as well as some new techniques to better approximate invariant manifolds. The talks will include applications to nonlinear geometric control, synchronization detectability, bubbling bifurcations, and constrained invariant manifolds in continuum mechanics.

**Organizer: Ira B. Schwartz**
*Naval Research Laboratory*

**Organizer: David S. Morgan**
*Naval Research Laboratory*

**8:30-8:55 Multi-scale Continuum Mechanics: Finding Constrained Invariant Sets**
Erik Bollt, Clarkson University; and Ira B. Schwartz and *David S. Morgan*, Naval Research Laboratory

**9:00-9:25 Singularities in the Solution Set of an Optimal Control Problem**
*Hinke M. Osinga*, University of Bristol, United Kingdom; and John Hauser, University of Colorado, Boulder

**9:30-9:55 Bubbling Bifurcations**
Brian R. Hunt, University of Maryland, College Park

**10:00-10:25 Synchronization of Noninvertible Systems**
Kresimir Josic, University of Houston

Tuesday, May 27

## MS9 (For Part II, see MS35)

### Applications of Difference Equations

*8:30 AM-10:30 AM*

*Room: Superior A*

Difference equations have had a tremendous impact of the development of dynamical systems. Indeed, the logistic map studied by Robert May in 1974, was one of the first instances of chaos found. Another well known example is the Henon map, which is not yet fully understood. Difference equations are particularly good tools for studying population dynamics and, more recently, with the work of Cushing and his coauthors, some aspects of ecology.

**Organizer: Judy A. Kennedy**
*University of Delaware*

**8:30-8:55 Anatomy of a Chaotic Attractor**
Jim Cushing, University of Arizona

**9:00-9:25 HIV Epidemics**
James A. Yorke, University of Maryland, College Park

**9:30-9:55 Competitive Exclusion in Discrete-Time Deterministic and Stochastic Epidemic Models with Multiple Pathogens**
Nadarajah Kirupaharan and Linda Allen, Texas Tech University

**10:00-10:25 Monarch Butterfly Metapopulation Dynamics**
Abdul-Aziz Yakubu, Howard University

Tuesday, May 27

## MS10 For Part II, see MS 24

### Elastic Rod Models and Applications

*8:30 AM-10:30 AM*

*Room: Superior B*

There has been a recent surge of interest in nonlinear elastic rod theory. Although the classical roots of the subject are in structural engineering, mathematical scientists have approached rod theory in recent years from many new perspectives - modeling, analysis and computation - in order to glean insight into the behavior of flexible structures, including several biological systems. As a consequence, several new and general results have been obtained in rod theory, with additional contributions to nonlinear analysis and dynamical systems. Our goal is to bring together a diverse group of researchers to highlight some of these results. This minisymposium complements another proposed minisymposium in this conference entitled Mechanical Models of DNA. DNA is a well-studied application of elastic rod theory.

**Organizer: Kathleen A. Hoffman**
*University of Maryland, Baltimore County*

**Organizer: Tim Healey**
*Cornell University*

**8:30-8:55 Stability of a Twisted Elastic Strut**
Randy Paffenroth, California Institute of Technology; *Kathleen A. Hoffman*, University of Maryland, Baltimore County; and Robert S. Manning, Haverford College

**9:00-9:25 Equilibira of Finite Elastic Rods with Intrinsic Curvature**
Tim Healey, Cornell University

**9:30-10:00 Thermal Fluctuations of Small Rings of Intrinsically Helical Elastic Rods**
Irwin Tobias, Rutgers University

**10:00-10:25 Stability of a Buckling Rod in a "Soft Wall" External Field**
Robert S. Manning, Haverford College

Tuesday, May 27

## MS11

### Dispersive Wave Turbulence

*8:30 AM-10:30 AM*

*Room: White Pine*

Spatiotemporally chaotic dispersive waves exhibit turbulent behavior. Charaterization of dispersive wave turbulence (weak turbulence) is the main focus of the minisymposium. Topics include studies of wave resonances, weak turbulence theory, which is a mean-field statistical description of dispersive wave turbulence. The symposia address the important recent progress in application of weak turbulence formalism in studying diverse physical phenomena ranging from phenomenological models to the internal waves in the ocean.

**Organizer: Yuri V. Lvov**
*Rensselaer Polytechnic Institute*

**8:30-8:55 Resonant Energy Transfer, Breaking Waves and Mixing**
Esteban G. Tabak, Courant Institute of Mathematical Sciences, New York University

**9:00-9:25 Chaotic and Turbulent Dynamics of Nonlinear Waves in One-dimension**
David Cai, Courant Institute of Mathematical Sciences, New York University

**9:30-9:55 Application of Weak Turbulence Theory to Fermi-Pasta-Ulam Model**
Peter R. Kramer, Rensselaer Polytechnic Institute

**10:00-10:25 Weak Turbulence and the Garrett-Munk Spectrum of Internal Waves in the Ocean**
Yuri V. Lvov, Rensselaer Polytechnic Institute

Tuesday, May 27

# MS12

## Applications Of Dynamical Systems and Non-linear Control Theory

*8:30 AM-10:30 AM*

*Room: Eagles Nest*

The estimation of methane is now important because there are controversial results on such emission all over the globe. Precise estimates of methane are difficult due to the large spatial and temporal variability in methane measured at different sites due to differences in climate, soil properties, fertilization and sources. In this minisymposium, the speakers will discuss a spatiotemporal continuous dynamic model and its proper mathematical analysis. The system of methane emission is sufficiently complex; it is unlikely that one can make any quantitative prediction about the system. However it is possible to reduce the number of degrees of freedom inherent in the system then a qualitative description may be possible.

**Organizer: Amit Chakraborty**
*University of Calcutta, India*

**Organizer: Dilip Kumar Bhattacharaya**
*University of Calcutta, India*

**8:30-8:55 Spatiotemporal Model and Its Application to Methane Emission System**
Amit Chakraborty, University Of Calcutta, India

**9:00-9:25 Dynamical System and Non-linear Control Therory**
Dilip Kumar Bhattacharaya, University Of Calcutta, India

**9:30-9:55 Difference Equations and Dynamical Systems with Some Applications**
Nitai Kundu, Institute Of Wetland, India

**10:00-10:25 Efficient Control Problem**
T. E. Aman, Balurghat College, India

# Coffee Break

*10:30 AM-11:00 AM*

*Room: Golden Cliff*

Tuesday, May 27

# IP1

## The Navier-Stokes Equations with Moving Interfaces and Surface Tension

*11:00 AM-12:00 PM*

*Room: Ballroom*

*Chair: Darryl Holm, Los Alamos National Laboratory*

The incompressible Navier-Stokes equations (NSE) on time-dependent domains arise in the study of either a single fluid with a free-surface, or in the context of multi-phase flows wherein the motion of two or more immiscible fluids is considered. In the presence of surface tension, the mathematical analysis (as well as the numerical computation) is a challenging task, because the mean curvature vector, given in the surface tension term, appears to induce too much derivative loss on the boundary; in fact, Newton iteration will fail to converge, and other iteration schemes must be constructed.

I will describe the analysis of surface-tension driven interface motion in both the short-time and long-time regimes. For short-time well-posedness of the NSE, I will present a technique, based on new types of energy laws of the linearized system. For long-time simulations, a generalization of the NSE is required to make sense of the mean curvature vector at the point of singularity. While viscosity solution techniques for the NSE have been employed when surface tension is assumed to be zero, with surface tension present such techniques are not known to hold. I will describe a phase-field model that fattens-up the sharp interface of the NSE and has long-time weak solutions. I will then explain how solutions of this phase-field model weakly converge to solutions of the NSE, as long as the NSE solutions exist.

**Steve Shkoller**
*University of California, Davis*

# Lunch Break

*12:00 PM-1:30 PM*

*Attendees on Their Own*

Tuesday, May 27

# IP2

## Sonoluminescence: Illuminating Bubbles

*1:30 PM-2:30 PM*

*Room: Ballroom*

*Chair: Laurette S. Tuckerman, LIMSI-CNRS, France*

Single sound driven gas bubbles in water can emit light. This remarkable phenomenon, discovered only in 1990 is called single bubble sonoluminescence. Its energy focusing power is 12 orders of magnitude. Two questions immediately arise: (i): When does this phenomenon occur? (ii): What is the light emitting mechanism? In the last years both of these questions could be resolved and the phenomenon could quantitatively be accounted for.

On question (i): For sonoluminescence to occur, the bubble collapse has to be violent enough to ensure strong enough adiabatic heating of the gas inside the bubble. Moreover, the bubble has to be shape stable, diffusively stable, and chemical stable. From these conditions the phase diagrams of sonoluminescence can be calculated. They are found to be in excellent quantitative agreement with measured phase diagrams .

Question (ii) could be addressed thanks to experiments dealing with the width and the intensity of the light pulses. It turned out that the light emitting process is thermal bremsstrahlung.

In the second part of the talk we will briefly address applications of collapsing bubbles: Either by snapping shrimp or in ultrasound diagnostics and local drug delivery.

**Detlef Lohse**
*University of Twente, Netherlands*

## Intermission

*2:30 PM-2:45 PM*

Tuesday, May 27

# CP1

## Faraday Waves: Symmetries, Forcing, and Quasipatterns

*2:45 PM-3:25 PM*

*Room: Ballroom I*

*Chair: Anne J. Catlla, Northwestern University*

**2:45-3:00 Impulsively Forced Faraday Waves**

Mary C. Silber and *Anne J. Catlla*, Northwestern University; and Jeff B. Porter, University of Leeds, United Kingdom

**3:05-3:20 Nearly Inviscid Faraday Waves in An Elliptical Container**

Jose Manuel Vega and *Maria Higuera*, Univ. Politecnica de Madrid, Spain; and Edgar Knobloch, University of Leeds, United Kingdom

Tuesday, May 27

# CP2

## Topics in Phase Synchronization

*2:45 PM-3:45 PM*

*Room: Ballroom II*

*Chair: Frank E. Moss, University of Missouri, St. Louis*

**2:45-3:00 The Crayfish Caudal Photoreceptor Neurons: Synchronization and Frequency Doubling**

Sonya Bahar, Weill Medical College of Cornell University; and *Frank E. Moss*, University of Missouri, St. Louis

**3:05-3:20 Detecting Phase-Locking: Synchronization Index Vs. Coherence Function**

Peter Tass and *Kevin Dolan*, Institute of Medicine Research Center, Jülich, Germany

**3:25-3:40 Experimental Phase Synchronizous Chua Oscillator**

*Epaminondas Rosa*, Illinois State University; Ibere L. Caldas and Murilo S. Baptista, University of Sao Paulo, Brazil; and Jose Sartorelli and Tiago Silva, Universidade de Sao Paulo, Brazil

Tuesday, May 27

# CP3

## 2-D and 3-D Turbulent Flows

*2:45 PM-3:25 PM*

*Room: Ballroom III*

*Chair: Yuan-Nan Young, Stanford University*

**2:45-3:00 Statistics of Levels in Turbulent Flow**

Frank Ham, Nagi Mansour, and *Yuan-Nan Young*, Stanford University

**3:05-3:20 Self-Preservation of Most Probable Energy in Shell Model of Isotropic Turbulence**

Mogens V. Melander, Southern Methodist University

Tuesday, May 27

# CP4

## Topics in Fluid Dynamics - I

*2:45 PM-3:45 PM*

*Room: Magpie A*

*Chair: Bruce Fabijonas, Southern Methodist University*

**2:45-3:00 Multi-Frequency Craick-Criminale Solutions to the Navier-Stokes Equations**

Darryl Holm, Los Alamos National Laboratory; and *Bruce Fabijonas*, Southern Methodist University

**3:05-3:20 Shear Layer Modeling Using $\alpha$ -Euler Equation**

Igor Mezic and *Thomas John*, University of California, Santa Barbara

**3:25-3:40 Periodic Vortex Motion on a Sphere**

Bharat Khushalani, University of Southern California

Tuesday, May 27

# CP5

## Predator-Prey Systems and Competing Species

*2:45 PM-3:45 PM*

*Room: Magpie B*

*Chair: Peter A. Braza, University of North Florida*

**2:45-3:00 Predator-Prey Dynamics with Disease in the Prey**

Peter A. Braza, University of North Florida

**3:05-3:20 Front Propagation and Segregation in a Reaction-Diffusion Model with Cross-Diffusion**

Benjamin Carreras, Vickie Lynch, and *Diego Del-Castillo-Negrete*, Oak Ridge National Laboratory

**3:25-3:40 Higher Codimension Bifurcations in Ecosystem Models**

Ulrike Feudel, University of Oldenburg, Germany; and *Thilo Gross*, Carl von Ossietzky Universitaet Oldenburg

Tuesday, May 27

# CP6

## Reconstructions from Time Series

*2:45 PM-3:45 PM*

*Room: Wasatch A*

*Chair: Ioana A. Triandaf, Naval Research Laboratory*

**2:45-3:00 Approximating Stable and Unstable Manifolds in Experiments**
Ioana A. Triandaf, Naval Research Laboratory

**3:05-3:20 Parameter Space Reconstruction from Experimental Time Series**
*Ulrich Parlitz*, University of Goettingen, Germany; and Gerrit Langer, German Aerospace Center, Goettingen, Germany

**3:25-3:40 Multiple Modeling Analysis of Chaotic Systems**
Luis A. Sandoval, Antonio Narino University, Columbia

Tuesday, May 27

# CP7

## Knot- and Braid-Solutions of ODEs

*2:45 PM-3:45 PM*

*Room: Wasatch B*

*Chair: Brian Spears, University of California, Berkeley*

**2:45-3:00 Knotted Invariant Manifolds in a System with QP Forcing**
Andrew J. Szeri and *Brian Spears*, University of California, Berkeley

**3:05-3:20 Fourth Order Differential Equations Via Braids**
Robert W. Ghrist, University of Illinois, Urbana-Champaign; *Jan Bouwe Van Den Berg*, University of Nottingham, United Kingdom; and Robert van Der Vorst, Vrije Universiteit Amsterdam, The Netherlands

**3:25-3:40 Towards Topological Analysis of Higher-Dimensional Chaos**
Robert Gilmore, Drexel University; and *Marc Lefranc*, PHLAM/Université Lille I, France

Tuesday, May 27

# CP8

## Homoclinic Orbits

*2:45 PM-3:45 PM*

*Room: Maybird*

*Chair: Richard Haberman, Southern Methodist University*

**2:45-3:00 Action and Period of Homoclinic and Periodic Orbits for the Unfolding of a Saddle-Center Bifurcation**
Richard Haberman, Southern Methodist University

**3:05-3:20 Homoclinic and Heteroclinic Connections in Perturbed Hamiltonian Systems with Saddle-Centers**
Kazuyuki Yagasaki, Gifu University, Japan

**3:25-3:40 Implicit Dynamical Systems: Solvability, Asymptotics, Number of Solutions**
Oleksandr E. Zernov, South Ukrainian State Pedagogical University

Tuesday, May 27

# CP9

## Interactions of Solitons and Localized Structures

*2:45 PM-3:45 PM*

*Room: Superior A*

*Chair: Roy Goodman, New Jersey Institute of Technology*

**2:45-3:00 Resonance and Capture of Sine-Gordon Solitons**

Roy Goodman, New Jersey Institute of Technology

**3:05-3:20 Interaction of Localized Structutures in the Swift-Hohenberg Equation**

Paul Mandel and *Mustapha Tlidi*, Université Libre de Bruxelles, Belgium; and Andrei Vladimirov, St. Petersburg State University, Russia

**3:25-3:40 2D-Spatial Dissipative Solitons Induced by a Saturable Absorber in Quadratic Media**

Mustapha Tlidi, Université Libre de Bruxelles, Belgium; and Alberto Barsella, Catherine Lepers, and *Majid Taki*, PHLAM - Universite de Lille, France

Tuesday, May 27

# CP10

## Topics in Delay and Difference Equations

*2:45 PM-3:45 PM*

*Room: Superior B*

*Chair: Claudia Lainscsek, University of California, San Diego*

**2:45-3:00 Nonlinear Oscillations in Microvascular Blood Flow**

Russell Carr, John B. Geddes, Fan Wu, and *Gabriel Withington*, University of New Hampshire

**3:05-3:20 Semi-Discretization of Time-Periodic Delay-Differential Equations**

Tamas Insperger and *Gabor Stepan*, Budapest University of Technology and Economics, Hungary

**3:25-3:40 Correspondence Between the Difference Equations and Differential Equations for Global Modeling**

Irina Gorodnitsky and *Claudia Lainscsek*, University of California, San Diego

Tuesday, May 27

# CP11

## Geometry and Control in PDE and Hamiltonian Systems

*2:45 PM-3:45 PM*

*Room: White Pine*

*Chair: Russell K. Jackson, Boston University*

**2:45-3:00 On the Stability of Pulses in Nonlinear Schrödinger Equations**

*Russell K. Jackson*, Boston University; and Christopher Jones, University of North Carolina

**3:05-3:20 A Priori Stable, a Priori Unstable and Bifurcating Systems, Frequency Maps and Instabilities**

*Anna Litvak-Hinenzon*, University of Warwick, United Kingdom; and Vered Rom-Kedar, The Weizmann Institute

**3:25-3:40 Controllability of N-Degree of Freedom Integrable Hamiltonian Systems**

Igor Mezic and *Umesh Vaidya*, University of California, Santa Barbara

# Coffee Break

*3:45 PM-4:15 PM*

*Room: Golden Cliff*

Tuesday, May 27

# MS13

## Swarming and Vortex Motions of Self-Propelled Biological Agents

*4:15 PM-6:15 PM*

*Room: Ballroom I*

Swarm theories have developed into objects of intense interest for physicists and mathematicians beginning with the pioneering work of Vicsek in 1995 that stimulated further development of models. However, directly related laboratory experiments have been difficult mainly due to size of the patterns and poor knowledge of the agent-agent interactions in actual animal swarms. This symposium addresses this point with summaries of current theory together with reports of new experiments on pattern formation in zooplankton. The five talks progress from single agent interactions with the environment through motions in defined external fields to emergent patterns or motions such as the interactive zooplankton-hydrodynamic vortex, fish schools and bird flocks.

**Organizer: Frank E. Moss**
*University of Missouri, St. Louis*

**Organizer: Anke Ordemann**
*University of Missouri, St. Louis*

**4:15-4:40 Stepping Through the Water**
Rudi Strickler, University of Wisconsin, Milwaukee

**4:45-5:10 Biological-Physical Interactions at the Size Scale of an Individual Copepod**
Houshuo Jiang, Woods Hole Oceanographic Institution

**5:15-5:40 Vortex Swarming of Biological Agents**
Gabor Balazsi, Northwestern University Medical School; and Frank E. Moss, Elizabeth Caspari, and *Anke Ordemann*, University of Missouri, St. Louis

**5:45-6:10 Emergent Properties in Biology: Are Fish Schools an Appropriate Model?**
*Julia Parrish*, University of Washington, Seattle; Daniel Grunbaum, University of Washington; and Steven Viscido, SAFS, University of Washington

Tuesday, May 27

# MS14

## Coherence Resonance and Noise-Induced Synchronization

*4:15 PM-6:45 PM*

*Room: Ballroom II*

The effect of noise on nonlinear dynamical systems has been an issue of fundamental importance. Two topics of recent interest are coherence resonance and noise-induced synchronization, both concerning enhancement of collective and coherent dynamics by noise. In this minisymposium, speakers will give overviews of these two phenomena and report forefront research. Theoretical, numerical, and experimental issues, and applications to signal processing in enginnering and biology will be addressed.

**Organizer: Ying-Cheng Lai**
*Arizona State University*

**Organizer: Juergen Kurths**
*Universität Potsdam, Germany*

**4:15-4:40 Coherence Resonance in Extended Systems**
Changsong Zhou and *Juergen Kurths*, Universität Potsdam, Germany

**4:45-5:10 Coherence Resonance in Chaotic Systems**
Zonghua Liu, Liqiang Zhu, and *Ying-Cheng Lai*, Arizona State University

**5:15-5:40 Coherence Resonance in Type I Stochastic Excitable Dynamics**
Benjamin Lindner and *Andre Longtin*, University of Ottawa, Canada

**5:45-6:10 Ghost Resonance in an Excitable Laser**
Claudio Mirasso, Universitat de les Illes Balears, Spain

**6:15-6:40 System Size Coherence Resonance**
Raul Toral, Universitat de les Illes Balears, Spain

Tuesday, May 27

# MS15

## Recent Progress in Fiber Optics

*4:15 PM-6:45 PM*

*Room: Ballroom III*

The continuously increasing demand for fast telecommunication networks triggered intense research efforts on fiber optics. Here, we mainly focus on the following intriguing subjects: short pulse propagation, randomness effects, and inter-channel pulse interactions. First, the use of very short pulses has become an essential, and a better understanding of propagation of such pulses is needed. A new equation describing the propagation of very short pulses in optical fibers will be presented and compared to the nonlinear Schroedinger equation. Second, numerical as well as theoretical results including the effects of inhomogeneous media, which pose fatal limitations on the performance of fiber optics systems, will be discussed. Finally, we will introduce a general perturbation theory describing inter-channel interactions between pulses in multi-channel systems.

**Organizer: Avner Peleg**
*CNLS, Los Alamos National Laboratory*

**Organizer: Yeojin Chung**
*CNLS, Los Alamos National Laboratory*

**4:15-4:40 Inter-channel Interactions Between Non-ideal Solitons**
Misha Chertkov, Los Alamos National Laboratory; Ildar Gabitov, University of Arizona and Los Alamos National Laboratory; and *Avner Peleg*, CNLS, Los Alamos National Laboratory

**4:45-5:10 Numerical Study of the Interaction Between Solitons and Radiation in Random Media**
Michael Chertkov, Los Alamos National Laboratory; Alexander Dyachenko, Igor Kolokolov, and Vladimir Lebedev, Landau Institute for Theoretical Physics, Russia; Ildar Gabitov, University of Arizona and Los Alamos National Laboratory; and *Yeojin Chung*, CNLS, Los Alamos National Laboratory

**5:15-5:40 Short Pulses in Optical Fibers: A New Equation**
Tobias Schaefer, University of North Carolina, Chapel Hill

**5:45-6:10 Optical Fibers and Random Media**
Chris Jones and *Rudy Horne*, University of North Carolina, Chapel Hill

**6:15-6:40 Dynamics of Thermally Loaded Optical Parametric Oscillators**
Keith Promislow and *Richard Moore*, Simon Fraser University, Canada

Tuesday, May 27

# MS16

## Stability and Regularity of Nonlinear Waves

*4:15 PM-7:15 PM*

*Room: Magpie A*

PDE's that conserve energy such as the non-linear Klein-Gordon equation, NLS, etc., can be written as infinite-dimensional Hamiltonian systems. The conservation of energy is a starting point for the stability analysis. For all of theese equations, there exist special or "distinguished" solutions, e.g. traveling waves. It is important to develop methods for understanding the behavior of solutions near the waves since they are characteristic feature of many physical phenomena. The topics will include different methods for determining stability/instability as well as regularity of the solutions for an array of nonlinear equations of mathematical physics. There have been lots of exciting mathematical advances in this direction during recent years with broad applications in areas like nonlinear optics, water-waves theory and mathematical physiology.

**Organizer: Weishi Liu**
*University of Kansas*

**Organizer: Milena Stanislavova**
*University of Massachuetts, Amherst*

**4:15-4:40 Pulse Dynamics in Nonlinear Fiber Arrays**
Bjorn Sandstede, Ohio State University; *Todd Kapitula*, University of New Mexico; and Panayotis Kevrekidis, University of Massachusetts, Amherst

**4:45-5:10 Lyapunov Exponents and the Essential Spectrum of the Linearized Euler Equations**
Yuri Latushkin, University of Missouri, Columbia

**5:15-5:40 Stability of Solitary Waves of the Green-Naghdi Equations**
Yi Li, Stevens Institute of Technology

**5:45-6:10 Dispersive Effects in a Modified Kuramoto-Sivashinsky Equation**
*Judith R. Miller*, Georgetown University; and Alex Iosevich, University of Missouri, Columbia

**6:15-6:40 Corners in Interface Propagation**
Arnd Scheel, University of Minnesota, Minneapolis

**6:45-7:10 Regularity of Ground States for DMNLS**
Milena Stanislavova, University of Massachuetts, Amherst

Tuesday, May 27

# MS17

## Stability and Pattern Formation in Dynamics on Networks

*4:15 PM-7:15 PM*

*Room: Magpie B*

The theory of random graphs and the study of coupled dynamical systems have evolved as two separate disciplines for many years. Recent work has begun to examine the relation between dynamics and network topology. This minisymposium intends to address two basic questions along this new direction. First, how is the stability of a synchronized state, where the state could be a fixed point, a limit cycle, or a chaotic attractor, affected by the interplay between network connectivity and the associated coupling strength matrix? Second, when the synchronized state loses stability, what is the nature of the resulting bifurcation? Can the notion of a Turing pattern be generalized to characterize the regular patterns that emerge from nontrivial (e.g. non-fixed-point) dynamical background? Our emphasis will be placed on the development of analytical techniques to treat these problems.

**Organizer: Lou Pecora**
*Naval Research Laboratory*

**Organizer: Mingzhou Ding**
*Florida Atlantic University*

**4:15-4:40 Algebraic Properties of Graphs and Network Synchronization**
Mauricio Barahona, Imperial College of London, United Kingdom

**4:45-5:10 General Stability Analysis of Coupled Dynamic Systems**
Yonghong Chen, Xi'an Jiaotong University, P.R. China

**5:15-5:40 Ordering and Pattern Formation in On-off Intermittency Desynchronization of Homogeneous Chaos**
Gang Hu, Beijing Normal University, China

**5:45-6:10 Generalized Turing Patterns in Coupled Dynamical Systems**
*Mingzhou Ding*, Florida Atlantic University; and Govindan Rangarajan, Indian Institute of Science, Bangalore, India

Tuesday, May 27

# MS17

*continued*

**6:15-6:40 Synchronization in Small-World Networks with a Time-Varying Coupling**
Martin Hasler, Swiss Federal Institute of Technology-Lausanne, Switzerland; Vladimir Belykh, Volga State Academy, Russia; and *Igor Belykh*, Swiss Federal Institute of Technology, Switzerland

**6:45-7:10 The Onset of Synchronism in Globally Coupled Ensembles of Chaotic and Periodic Oscillators**
Ernest Barreto and *Paul So*, George Mason University

Tuesday, May 27

# MS18

## Ergodic Theory of Hyperbolic and Skew-Product Dynamical Systems

*4:15 PM-7:15 PM*

*Room: Wasatch A*

In this minisymposium we present a spectrum of recent results on the ergodic and topological properties of dynamical systems which are hyperbolic or of skew-product form. Such mathematical models arise naturally in applications, especially in systems with symmetry. Much progress has been made in the last few years on these topics.

**Organizer: Andrew Torok**
*University of Houston*

**Organizer: Matthew Nicol**
*University of Surrey, United Kingdom*

**4:15-4:40 Intermittency Near Bifurcations in Deterministic and Randomly Perturbed Systems**
Ale Jan Homburg, University of Amsterdam, Netherlands; and *Todd Young*, Ohio University

**4:45-5:10 Infimum of Entropy for Hyperbolic Attractors**
Miaohua Jiang, Wake Forest University

**5:15-5:40 On the Ergodicity of Weyl Cocycles**
Mahesh Nerurkar, Rutgers University, Camden

**5:45-6:10 Topological Transitivity of Extensions of Anosov Diffeomorphisms with Non-compact Fiber**
Viorel Nitica, West Chester University

**6:15-6:40 Statistical Properties of Equivariant Dynamical Systems**
Ian Melbourne, Andrew Scott, and *Matthew Nicol*, University of Surrey, United Kingdom

**6:45-7:10 Stable Ergodicity of Smooth Compact Group Extensions of Hyperbolic Set**
Ian Melbourne, University of Surrey, United Kingdom; and Michael Field and *Andrew Torok*, University of Houston

Tuesday, May 27

# MS19

## Geometric Dynamics

*4:15 PM-7:15 PM*

*Room: Wasatch B*

In this session we will present some recent trends in the field of geometric dynamics. Two kinds of dynamical systems will be discussed--mechanical systems and gradient flows on Lie groups and group orbits. In particular, the following areas will be addressed: reduction of variational principles in mechanics, bifurcations of relative equilibria in Hamiltonian systems, applications of group dynamics to control problems, dynamics of generalized double bracket flows, and integrability and conservation laws in constrained systems. The effectiveness of geometric tools such as symmetry and momentum maps will be emphasized.

**Organizer: Anthony M. Bloch**
*University of Michigan, Ann Arbor*

**Organizer: Dmitry V. Zenkov**
*North Carolina State University*

**4:15-4:40 Reduction of Hamilton's Phase Space Principle**
Jerrold E. Marsden, California Institute of Technology

**4:45-5:10 Dynamics on SU(n) and Adaptive Optics**
P.S. Krishnaprasad, University of Maryland, College Park

**5:15-5:40 Bifurcations of Hamiltonian Relative Equilibria**
Mark Roberts, University of Surrey, United Kingdom

**5:45-6:10 Integrable Particle Interactions on Curves and Surfaces**
Paul K. Newton, University of Southern California

**6:15-6:40 The Geometry and Dynamics of Generalized Double Bracket Equations**
Anthony M. Bloch, University of Michigan, Ann Arbor

**6:45-7:10 Momentum Conservation in Nonholonomic Mechanics**
Dmitry Zenkov, North Carolina State University

Tuesday, May 27

# MS20

## Reduced-Order Dynamics of Fluids and Flames

*4:15 PM-7:15 PM*

*Room: Maybird*

This minisymposium addresses reduced-order modeling and analysis of fluid systems using methods related to the Proper Orthogonal Decomposition (POD), which gives an empirical orthogonal basis of modes that optimally capture, e.g., energy content. The focus is on analyzing coherent structures in these flows, and developing approximate low-dimensional models. The different talks illustrate features and limitations of the POD method, and advantages and disadvantages of the related methods of archetypes and balanced truncation.

**Organizer: Clancy W. Rowley**
*Princeton University*

**Organizer: Jeffrey Moehlis**
*Princeton University*

**4:15-4:40 Models for Turbulent Plane Couette Flow Using the Proper Orthogonal Decomposition**
Jeff Moehlis, Phil Holmes, and *Troy Smith*, Princeton University

**4:45-5:10 Reduced-order Analysis of the Compressible Turbulent Jet**
*Peter Blossey*, University of Maryland, College Park; Jonathan B. Freund, University of Illinois, Urbana-Champaign; and Thomas R. Bewley, University of California, San Diego

**5:15-5:40 Multi-Scale Analysis of a Jet Flow Using POD**
Ramons Reba, Thierry Maeder, and *Gregory Hagen*, United Technologies Research Center

**5:45-6:10 Archetypal Dynamics of Cellular Flames**
Emily F. Stone, Utah State University

**6:15-6:40 Error, Sensitivity, and Computational Complexity of POD**
*Muruhan Rathinam*, University of Maryland, Baltimore County; and Linda R. Petzold, University of California, Santa Barbara

**6:45-7:10 Links Between POD and Balanced Truncation**
Clancy W. Rowley, Princeton University

Tuesday, May 27

# MS21

## Extracting Salient Features of Embedded Time Series with Applications to Health Monitoring

*4:15 PM-7:15 PM*

*Room: Superior A*

Analysis of features from an embedded time series continues to be an important area of study in nonlinear systems. Time series, obtained from a system through either ambient exitation(e.g. a mammalian neuronal network) or applied loading (e.g. a chaotically driven structure) exhibit changes in the embedded attractor when the underlying system is damaged or perturbed. Since we discuss time series which are obtained in an experimental setting, methods of analysis which address noise and/or ambient vibration are desirable. The object of this minisymposium is to showcase new methods of feature extraction and data analysis which can be used to detect damage and/or monitor the health of the underlying structures.

**Organizer: Linda Moniz**
*Naval Research Laboratory*

**Organizer: Jonathan Nichols**
*Naval Research Laboratory*

**4:15-4:40 Vibration-Based Damage Assessment Using Novel Function Statistics with Multiple Time Series**
Jonathan Nichols, Michael D. Todd, Thomas Carroll, Lou Pecora, Steven Trickey, and *Linda Moniz*, Naval Research Laboratory

**4:45-5:10 Damage Detection and Localization Using a Steady-State Chaotic Dynamic Approach**
Jonathan Nichols, Naval Research Laboratory

**5:15-5:40 Phase-Space Warping: A General Approach to Machinery Diagnosis and Prognosis**
Joseph Cusumano, Pennsylvania State University

**5:45-6:10 Detecting Nonlinear Interactions in Biological Systems**
Theoden Netoff, Boston University

**6:15-6:40 A Study of Measurement Noise in Chaotic Signals**
David Chelidze and *Kenneth Hartt*, University of Rhode Island

**6:45-7:10 Quantifying Wave Propagation Through a Composite Joint: Application to Structural Health Monitoring**
Christy Nichols, Duke University

Tuesday, May 27

# MS22

## Simulation and Modeling of Multi-Scale Fluid Motion and Turbulence

*4:15 PM-7:15 PM*

*Room: Superior B*

This minisymosium will focus on recently developed techniques for the modeling and simulation of fluid flow wherein so many spatial (and/or time) scales are activated as to make computational approximation prohibitively expensive. Issues to be addressed include (1) turbulence modeling for both compressible and incompressible flow founded upon the Lagrangian averaging framework, wherein variational methods are combined with G.I. Taylor's frozen turbulence hypothesis to produce closed models of large-scale flow, (2) atmospheric flows wherein inertia-gravity waves caused by rotation are removed using variational asymptotics, (3) new PDE techniques involving degenerate parabolic equations, and (4) atomostic and continuum simulation of nano-fluidics.

**Organizer: Steve Shkoller**
*University of California, Davis*

**Organizer: Darryl Holm**
*Los Alamos National Laboratory*

**4:15-4:40 Lagrangian Averaged Navier-Stokes-alpha (LANS-alpha) Model for Turbulence**
Darryl Holm, Los Alamos National Laboratory

**4:45-5:10 Variational Asymptotics for Rotating Fluids Near Geostrophy**
Marcel Oliver, International University Bremen, Germany

**5:15-5:40 Turbulent Flows in Weighted Sobolev Spaces Using the Anisotropic Lagrangian Averaged Navier-Stokes Equations**
Daniel Coutand, University of California, Davis

**5:45-6:10 Averaging and Filtering of Lagrangian Fluid Systems**
Matthew West, University of California, Davis

**6:15-6:40 Numerical Simulations of Isotropic Homogeneous Turbulence Using the Lagrangian Averaged Navier Stokes-$\alpha$ Equations**
Kamran Mohseni, University of Colorado, Boulder

**6:45-7:10 Atomistic/Continuum Simulation of Nano-Fluidics**
Shiyi Chen, Johns Hopkins University

Tuesday, May 27

# MS23 For Part II, see MS 45

## Synchrony in Neuroscience - Part I

*4:15 PM-7:15 PM*

*Room: White Pine*

Oscillations generated by the synchronous activity of networks of neurons are believed to play a fundamental role in neuronal processing. Dynamical systems theory has been very successful in analyzing and understanding synchronous behavior in models of such networks. This symposium will focus on recent theoretical and experimental results on synchronized behavior in neuronal networks, with an emphasis on the role of dynamical systems theory in modeling and experimental research. The questions addressed will include the role of noise and network architecture in the generation of synchronous behavior, and extension of results on small networks to networks of many neurons.

**Organizer: Kresimir Josic**
*University of Houston*

**Organizer: Stefano Boccaletti**
*Istituto Nazionale di Ottica Applicata, Italy*

**4:15-4:40 Temporal Coding Properties of Coupled Oscillator Neuron Models Exhibiting Synchrony**
Jason Middleton, University of Ottawa, Canada

**4:45-5:10 Synchronized Rhythms and the Flow of Motor Information**
David H. Terman, The Ohio State University; and *Jonathan E. Rubin*, University of Pittsburgh

**5:15-5:40 Synchrony in Model Neurons in an Electric Field**
Eun-Hyoung park, Paul So, Steven Schiff, and *Ernest Barreto*, George Mason University

**5:45-6:10 Loss of Rhythms in Neuronal Networks as a Result of Too Much Drive to the Inhibitory Cells**
Nancy Kopell, Boston University; and *Christoph Borgers*, Tufts University

**6:15-6:40 Random Dynamics and Entrainment to Synaptic Inputs**
*Jason Ritt*, Massachusetts Institute of Technology; and Nancy J. Kopell, Boston University

**6:45-7:10 Subthreshold Oscillations and Resonance in Neurons**
Eugene M. Izhikevich, The Neurosciences Institute

Tuesday, May 27

## Dinner Break

*7:15 PM-8:30 PM*

*Attendees on Their Own*

## SIAM Activity Group on Dynamical Systems Prize Session

*8:30 PM-9:30 PM*

*Ballroom*

*Chair: David W. McLaughlin, Courant Institute of Mathematical Sciences, New York University*

**The J. D. Crawford Prize**, established in 2000, is awarded to one individual for recent outstanding work on a topic in nonlinear science, as evidenced by a publication in English in a peer-reviewed journal within the four calendar years preceding the SIAG/DS meeting at which the prize is awarded. This year's awardee is Yannis Kevrekidis, Princeton University.

**The Jürgen Moser Lecture**, is awarded to a person who has made distinguished contributions to nonlinear science. The term 'nonlinear science' is used in the spirit of the SIAG/DS meetings; specifically it includes dynamical systems theory and its applications as well as experiments and computations/simulations. This year's awardee is David Ruelle, Institut des Hautes Etudes Scientifiques, France.

Tuesday, May 27

## The Jürgen Moser Lecture:

## Is There a Natural Dynamics for Systems with Many Degrees of Freedom

*8:45 PM-9:30 PM*

*Room: Ballroom*

*Chair: David W. McLaughlin, Courant Institute of Mathematical Sciences, New York University*

KAM theory and the Fermi-Pasta-Ulam experiments show that large systems can have nonhyperbolic behavior. Statistical mechanics seems however to conform to an interpretation based on uniform hyperbolicity and SRB states (at equilibrium and also outside of equilibrium). How can one reconcile this interpretation with the fact that real systems are probably not uniformly hyperbolic? We shall discuss some facts (about SRB states and their dependence on parameters) and some possibilities.

**David Ruelle**
*Institut des Hautes Etudes Scientifiques, France*

# Wednesday, May 28

## Registration

*8:00 AM-4:30 PM*

*Room: Ballroom Lobby*

## Game Room

*8:00 AM-12:00 AM*

*Room: Eagles Nest*

## Announcements

*8:15 AM-8:30 AM*

*Room: Ballroom II*

Wednesday, May 28

# MS24 (For Part I, see MS 10)

## Elastic Rod Models and Applications

*8:30 AM-10:30 AM*

*Room: Superior B*

There has been a recent surge of interest in nonlinear elastic rod theory. Although the classical roots of the subject are in structural engineering, mathematical scientists have approached rod theory in recent years from many new perspectives - modeling, analysis and computation - in order to glean insight into the behavior of flexible structures, including several biological systems. As a consequence, several new and general results have been obtained in rod theory, with additional contributions to nonlinear analysis and dynamical systems. Our goal is to bring together a diverse group of researchers to highlight some of these results. This minisymposium complements another proposed minisymposium in this conference entitled Mechanical Models of DNA. DNA is a well-studied application of elastic rod theory.

**Organizer: Kathleen A. Hoffman**
*University of Maryland, Baltimore County*

**Organizer: Tim Healey**
*Cornell University*

**8:30-8:55 The Mechanics of Multi-stranded Plies: Applications to Fibrous Proteins**
*Sebastien Neukirch*, Bernoulli Institute, EPFL; and Gert Heijden, van der, University College of London, United Kingdom

**9:00-9:25 Dynamics and Stability of Deformable Rods**
Stuart Antman, University of Maryland, College Park

**9:30-9:55 Bifurcation of Compressed Hemitropic Rods**
Chris Papadopoulos, University of Wisconsin, Milwaukee

**10:00-10:25 Localized Waves in Elastic Rods: Existence and Stability**
Alain Goriely, University of Arizona

Wednesday, May 28

# MS25

## Methods in Nonlinear Time Series Analysis

*8:30 AM-10:30 AM*

*Room: Ballroom III*

The analysis of time series data sampled from deterministic dynamical systems requires an understanding of the typical behaviour of dynamical systems in general, coupled with efficient reliable techniques for extracting information from the given data. Often, predictions must be made with at best rough knowledge of the underlying dynamics and with noisy data. The speakers in this minisymposium will present a cross-section of recent results in this area, introducing new ideas in conjunction with the development of existing themes. The talks also emphasize practical aspects of times series analysis and point towards applications such as weather forecasting or medical diagnosis.

**Organizer: Ian Melbourne**
*University of Surrey, United Kingdom*

**Organizer: Georg A. Gottwald**
*University of Sydney, Australia*

**8:30-8:55 Learning About Reality From Observation**
James A. Yorke, University of Maryland, College Park

**9:00-9:25 Indistinguishable States: What is "Uncertainty in the Initial Condition" Really?**
Leonard Smith, University of Oxford, United Kingdom

**9:30-9:55 Data Analysis in Big Dynamical Systems: Applications to Weather Forecasting**
Brian R. Hunt, University of Maryland, College Park; Jim Yorke, Ed Ott, Eugenia Kalnay, and Istvan Szunyogh, University of Maryland; and *Eric J. Kostelich*, Arizona State University

**10:00-10:25 A New 0-1 Test for Chaos**
Ian Melbourne, University of Surrey, United Kingdom; and *Georg A. Gottwald*, University of Sydney, Australia

Wednesday, May 28

# MS26

## Non-integrable Hamiltonians - Analysis and Applications

*8:30 AM-10:30 AM*

*Room: Wasatch B*

Arising in a variety of physical and mechanical systems, non-integrable Hamiltonian flows admit complicated types of solutions, with characteristics that are not well understood even for low dimensional systems. Analyzing the behavior of invariant manifolds, structure of resonances, and bifurcations in the near-integrable limit shed light on different aspects of the dynamics. On the other hand, understanding the properties of nominal dynamics allows devising perturbations that serve as efficient methods to control original systems. Applications of these results are important in such diverse fields as satellites' motion, plasma physics and fluid mixing.

**Organizer: Vered Rom-Kedar**
*The Weizmann Institute*

**Organizer: Dmitri L. Vainchtein**
*University of California, Santa Barbara*

**8:30-8:55 Control of Hamiltonian Systems with Integrable Nominal Dynamics**
Umesh Vaidya and *Igor Mezic*, University of California, Santa Barbara

**9:00-9:25 On the Break-up of Shearless Invariant Tori in the Standard Nontwist Map**
Amit Apte, Alex Wurm, and *Philip Morrison*, University of Texas, Austin

**9:30-9:55 Bailout Embeddings, Targetting KAM Tori and Hamiltonian Blow-out Bifurcations**
Oreste Piro, Universidad de las Islas Baleares, Spain

**10:00-10:25 Hamiltonian Homoclinic Dynamics and Symplectic Topology**
Lev Lerman, Nizhni Novgorod State University, Russia

Wednesday, May 28

# MS27 (For Part I, see MS 2)

## Nonlinear Dynamics in Crystal Growth Processes - Part II

*8:30 AM-10:30 AM*

*Room: Ballroom II*

Various modern crystal growth processes on which electronics industry is based on exhibit rich nonlinear dynamics. This minisymposium will cover wide spectrum of nonlinear phenomena in crystal growth, like morphological instabilities in epitaxial solid films, phase-field models, grain boundary motion, faceting of thermodynamically unstable surfaces, monte-carlo simulations, instabilities in step-flow growth, electrodeposition, and other important phenomena.

**Organizer: Alexander A. Golovin**
*Northwestern University*

**8:30-8:55 Feedback Control of Morphological Instabilities**
Vadim Panfilov, University of Nevada, Reno; Alexander A. Golovin and Tatyana Savin, Northwestern University; and Valeria Gubareva, Assaf Hari, and *Alexander Nepomnyashchy*, Technion - Israel Institute of Technology, Israel

**9:00-9:25 Faceting and Roughening of a Growing Crystal Surface by Surface-Diffusion Mechanism**
Alexander A. Golovin, Stephen H. Davis, Peter Voorhees, and *Tatiana Savin*, Northwestern University; and Alexander Nepomnyashchy, Technion - Israel Institute of Technology, Israel

**9:30-9:55 Nonclassical Traveling Wave Solutions: Coupling Motion by Mean Curvature with Surface Diffusion**
*Amy Novick-Cohen*, Technion IIT, Haifa, Israel; Arkady Vilenkin, Hebrew University of Jerusalem, Israel; and Jacob Kanel, Technion - Israel Institute of Technology, Israel

**10:00-10:25 The Coarsening Dynamics of Faceted Crystal Surfaces**
Stephen J. Watson, Northwestern University

Wednesday, May 28

# MS28 (For Part I, see MS 1)

## Phase Synchronization of Chaotic Systems: Theory and Applications - Part II

*8:30 AM-10:30 AM*

*Room: Ballroom I*

Phase synchronization (PS) of chaotic systems has attracted a wide interest in the scientific community. This minisymposium reports on recent advancements in the theoretical understanding of the role of noise in inducing phase synchronized states, and presents several experimental examples of PS in plasma physics, in fluid dynamics and in nonlinear optics.

**Organizer: Stefano Boccaletti**
*Istituto Nazionale di Ottica Applicata, Italy*

**Organizer: Epaminonda Rosa, Jr.**
*Illinois State University*

**8:30-8:55 Noise-induced Phase Synchronization**
*Chansong Zhou* and Juergen Kurths, Universität Potsdam, Germany

**9:00-9:25 Competition Between Two Signals for Phase Synchronism of a Chaotic Process**
Edward Ott and *Romulus Breban*, University of Maryland, College Park

**9:30-9:55 Phase Synchronization in Convective Experiments**
Diego Maza and *Hector L. Mancini*, Universidad de Navarra, Spain

**10:00-10:25 A Geometric Theory of Chaotic Phase Synchronization**
*Margaret Beck*, Boston University; and Kreso Josic, University of Houston

Wednesday, May 28

# MS29

## Properties of Granular Materials

*8:30 AM-10:30 AM*

*Room: Magpie A*

There has been great excitement in recent times as researchers have probed various aspects of granular materials. This minisymposium will focus on the identification of key properties of dense and gas-like granular states that would allow the development of new mathematical and theoretical formulations. Our understanding of what constitute the basic mathematical description of granular systems remains a challenge. Recent work suggests that descriptions for the gas-like phase are reasonably accurate. However, descriptions of dense phases remains a considerable challenge, as does the transition between dense and gas-like phases.

**Organizer: Robert Behringer**
*Duke University*

**Organizer: Michael Shearer**
*North Carolina State University*

**8:30-8:55 Granular Shear Flow: Memory in Sand**
Wolfgang Losert, University of Maryland, College Park

**9:00-9:25 Phase Transitions, Coarsening and Patterns and Electrostatically Drivengranular Media**
Wai Kwok, Yuri Tolmachev, Maksim Sapozhnikov, and *Igor Aronson*, Argonne National Laboratory

**9:30-9:55 Shear Instabilities in Granular Flows**
Ben Glasser and *Troy Shinbrot*, Rutgers University

**10:00-10:25 Coarse-Grained Stability and Bifurcation Analysis of Granular Flows**
D. Barkley, University of Warwick, United Kingdom; Harry Swinney, J. Swift, and *Sung J. Moon*, University of Texas, Austin; and IOANNIS Kevrekidis, Princeton University

Wednesday, May 28

## MS30 (For Part I, see MS 6)

### Scientific Simulation Using Python -- Part II

*8:30 AM-10:30 AM*

*Room: Wasatch A*

See description in Part 1, MS6

**Organizer: Raymond T. Pierrehumbert**
*University of Chicago*

**8:30-8:55 User Interface Design Patterns for Interactive Modeling with Python**
Anatoli Yashin and *Serge Boiko*, Max Planck Institute for Demographic Research, Germany

**9:00-9:25 Agent Based Modelling of HIV Evolution**
Simon D. Frost, University of California, San Diego

**9:30-9:55 Development of an Integrated, Multidisciplinary Water Quality Model Using Python**
Mike Mueller, Dresden Groundwater Research Center, Germany

**10:00-10:25 Open Discussion of Future Evolution of Python**
Raymond T. Pierrehumbert, University of Chicago

Wednesday, May 28

## MS31

### Stability, Dynamics, and Asymptotics of Hamiltonian Nonlinear Partial Differential Equations

*8:30 AM-10:30 AM*

*Room: Magpie*

From the early contexts of fluids and plasmas/lasers, to the more modern studies of nonlinear optical fibers, waveguides, and photonic materials, and to the exciting new world of matter waves in Bose-Einstein condensates, the range of applications in which Hamiltonian nonlinear partial differential equations arises is rich and diverse. With a particular view towards physical applications, in recent years there has been a considerable amount of progress in studying the dynamics of solitary waves associated with Hamiltonian systems. This minisymposium will address fundamental issues such as the stability of coherent structures and their interaction dynamics in these systems. We expect this to be a very exciting opportunity for dynamical systems people to learn about the current thrusts of research in this rapidly evolving field.

**Organizer: Todd Kapitula**
*University of New Mexico*

**Organizer: Panayotis Kevrekidis**
*University of Massachusetts, Amherst*

**8:30-8:55 Instability of Local Deformations of an Elastic Rod**
Stephane Lafortune and *Joceline Lega,* University of Arizona

**9:00-9:25 Evans Function Analysis of Stationary Light Transmission in Nonlinear Photonic Structures**
Dmitry Pelinovsky, McMaster University, Canada

**9:30-9:55 Vortex Lattices in Bose-Einstein Condensates**
Ricardo Carretero, San Diego State University, P.G. Kevrekidis, University of Massachusetts, I. G. Kevrekidis, Princeton University, D. Maroudas, University of Massachusetts, D. J. Frantzeskakis, University of Athens, Greece

**10:00-10:25 Spectral Stability of Localized Vortices for Nonlinear Schrödinger Equations**
Henry Warchall, National Science Foundation, and *Robert Pego*, University of Maryland, College Park

Wednesday, May 28

## MS32 (For Part II, see MS 54)

### Stochastic Modeling and Statistical Description of Spatially Extended Nonlinear Dynamics

*8:30 AM-10:30 AM*

*Room: Maybird*

Many systems involve such complicated chaotic dynamics over a wide range of spatiotemporal scales that they can be naturally described by statistical methods rather than detailed description of individual trajectories. In this minisymposium we will present several interdisciplinary problems and discuss modern theoretical and numerical approaches in characterizing their statistical properties. In particular, we will present new results on the equilibrium statistical mechanics for truncated analogs of conservative PDE's, statistical long time dynamics of nonlinear deterministic and stochastic differential equations, and stochastic mode-reduction in systems with separation of time scales.

**Organizer: Gregor Kovacic**
*Rensselaer Polytechnic Institute*

**Organizer: Ilya Timofeyev**
*University of Houston*

**8:30-8:55 Equilibrium Statistical Mechanics for Spectral Truncations of Conservative PDE's**
*Ilya Timofeyev*, University of Houston; and Andrew Majda, Courant Institute of Mathematical Sciences, New York University

**9:00-9:25 Statistical Description of a Spectral Truncation of the Burgers-Hopf Equation**
*Gregor Kovacic*, Rensselaer Polytechnic Institute; Andrew Majda and Rafail Abramov, Courant Institute of Mathematical Sciences, New York University; and Ilya Timofeyev, University of Houston

**9:30-9:55 Discrete Approximations with Additional Conserved Quantities: Deterministic and Statistical Behavior**
Andrew Majda and *Rafail Abramov*, Courant Institute of Mathematical Sciences, New York University

**10:00-10:25 Attractors of the Driven-damped, Spectral-truncated Burgers Equation**
Eric Vanden-Eijnden and *David Cai,* Courant Institute of Mathematical Sciences, New York University

Wednesday, May 28

# MS33

## Techniques of Neural Computing: Exploiting Changes in Synaptic Input

*8:30 AM-10:30 AM*

*Room: Superior A*

Neuronal activity is often mediated by synaptic input whose strength and timing may change due to plasticity, or more simply, to firing rate changes of presynaptic neurons. In this minisymposium, mechanisms which change synaptic input, and their resulting effects, will be discussed. Speakers will present novel hypotheses on how neurons transform changing synaptic inputs into mechanisms for filtering, gain amplification, synchrony and phase coding. In sum, the speakers will demonstrate that neurons possess vast sets of tools allowing them to make complex calculations in the face of varying inputs. The mathematical and modeling techniques presented are widely applicable, and will be of general interest to a math-neuro audience.

**Organizer: Amitabha K. Bose**
*New Jersey Institute of Technology*

**8:30-8:55 A Mechanism for High-Pass Filtering of Neuronal Signals**
Richard Bertram, Florida State University

**9:00-9:25 Divisive Gain Modulation through Noisy Background Synaptic Input**
Frances Chance, New York University/ Center for Neural Sciences

**9:30-9:55 The Effects of Plasticity in Networks of Neural Oscillators**
G Bard Ermentrout, University of Pittsburgh

**10:00-10:25 Phase Maintenance in Neuronal Networks**
Amitabha K. Bose, New Jersey Institute of Technology

Wednesday, May 28

# MS34

## Turbulent Dynamics in Geophysical Flows

*8:30 AM-10:30 AM*

*Room: White Pine*

The dominant nonlinear dynamics in geophysical flows involves the interactions between vortices, waves and large-scale mean flows. In the atmospheric context, these are high and low pressure cells (vortices), Rossby waves and the jetstream; and in the oceanic setting, these are eddies and the major currents. Geophysical flows of this sort are highly nonlinear, and are distinguished from familiar fluid flows by density stratification and Coriolis effects. Although the physical geometry of the terrestrial atmosphere and oceans have a shallow aspect ratio in the vertical (1-10 km) to the horizontal (10-1000 km), by their density-stratified nature, the vertical structures of these flows cannot be ignored.

Assembled for this mini-symposium are studies which seek to characterize turbulent flows and to ascertain their influences on larger scale flow structures. Understanding is derived by identifying the simpler dynamical mechanisms which underlie the complex nonlinear interactions that are found in these geophysical PDE models.

**Organizer: David J. Muraki**
*Simon Fraser University, Canada*

**8:30-8:55 Dynamics in a World Driven by Turbulent Diffusion**
Esteban G. Tabak, Courant Institute of Mathematical Sciences, New York University

**9:00-9:25 Generation of Large-scale Jets, Vortices and Layers from Near Resonant Interactions of Fast and Slow Waves**
Leslie Smith, University of Wisconsin, Madison

**9:30-9:55 The Coherence of Turbulence**
Fabian Waleffe, University of Wisconsin, Madison

**10:00-10:25 Vortex Dynamics on the Tropopause**
David J. Muraki, Simon Fraser University, Canada

# Coffee Break

*10:30 AM-11:00 AM*

*Room: Golden Cliff*

Wednesday, May 28

# IP3

## What is the Design Trick by Which Natural Selection Evolved Such Astonishingly Robust Genetic Networks?

*11:00 AM-12:00 PM*

*Room: Ballroom*

*Chair: Mary Lou Zeeman, University of Texas, San Antonio*

We used ordinary differential equations expressing mass action kinetics to model temporal changes in expression levels of RNAs and proteins in each of many neighboring cells. We studied several different genetic modules, best characterized experimentally in fruit fly embryos, but operating as well in most complex animals. We asked whether the experimentally proven interactions among genes and their products in these modules could explain the spatio-temporal patterns of gene expression those modules are known to make during early fruit fly development -- patterns that prefigure major features of the future larval body. It takes many (50 to 100) parameters to quantify the strengths and functional forms of the various interactions among the genes and their products, but none has an experimentally measured value. We performed vast computations to sample huge "boxes" in high-dimensional parameter space to ascertain the measure of the set of points in parameter space that would cause the model network to mimic correctly the spatio-temporal pattern formation performance of the real network. The measure of this set of 'good' points turned out to be unexpectedly huge, corresponding to robustness of the network which would be astonishing were it not essential to make complex genetic modules functionally heritable. The real networks we have studied are more complicated, and involve more genes, than any sophomore applied mathematician would need in a made-up model that creates the right spatial pattern. The simple made-up models we have constructed turn out not to be robust. We would like to understand, but don't yet understand, how natural selection crafted networks whose spatio-temporal pattern-formation repertoires

seems to be encoded mysteriously in the topology of of the network's conections, rather than in the strengths/functional forms of those connections.

**Garrett Odell**
*University of Washington*

## Lunch Break

*12:00 PM-1:30 PM*

*Attendees on Their Own*

Wednesday, May 28

# IP4

## Equation-Free Multiscale Computation: Enabling Microscopic Simulators to Perform System-Level Tasks

*1:30 PM-2:30 PM*

*Room: Ballroom*

*Chair: Charles R. Doering, University of Michigan, Ann Arbor*

I will discuss a framework for computer-aided multiscale analysis, which enables models at a "fine" (microscopic/stochastic) level of description to perform modeling tasks at a "coarse" (macroscopic, systems) level.

In traditional modeling, macroscopic equations are first derived from microscopic models, and then analyzed with available continuum methods. Our equation-free (EF) approach bypasses the derivation of macroscopic evolution equations, provided these equations conceptually exist but are not available in closed form. The mathematics-assisted development of a computational superstructure enables alternative descriptions of the problem physics (LB, KMC, MD, BD microscopic simulators), executed over relatively short time and space scales, to perform systems level tasks (integration over relatively large time and space scales, "coarse" bifurcation analysis, but also optimization and control tasks) directly.

**Yannis Kevrekidis**
*Princeton University*

## Intermission

*2:30 PM-2:45 PM*

Wednesday, May 28

# CP12

## Quasi-Geostrophic Flows

*2:45 PM-3:45 PM*

*Room: Ballroom I*

*Chair: Keith A. Julien, University of Colorado, Boulder*

**2:45-3:00 Stably-Stratified and Unstably-Stratified Quasigeostrophic Flows**

Joseph Werne, Colorado Research Associates/NWRA; *Keith A. Julien*, University of Colorado, Boulder; and Edgar Knobloch, University of Leeds, United Kingdom

**3:05-3:20 Dynamics of a Quasigeostrophic Ellipsoidal Vortex Moment Model**

Jeffrey Weiss, University of Colorado; and Keith A. Julien and *Neil D. Burrell*, University of Colorado, Boulder

Wednesday, May 28

# CP13

## Applications in Celestial Mechanics

*2:45 PM-3:45 PM*

*Room: Ballroom II*

*Chair: Marian Gidea, Northeastern Illinois University*

**2:45-3:00 Relative Equilibria and Saari's Conjecture**

Gareth E. Roberts, College of the Holy Cross

**3:05-3:20 Chaotic Orbits in a Perturbed Sitnikov Problem**

Marian Gidea, Northeastern Illinois University

**3:25-3:40 Optimizing the Earth to Mars Trajectory**

Bill Clark, University of Texas, Austin

Wednesday, May 28

# CP14

## Analytical and Numerical Methods for Bifurcations

*2:45 PM-3:45 PM*

*Room: Ballroom III*

*Chair: Mark J. Friedman, University of Alabama*

**2:45-3:00 Continuation of Invariant Subspaces for Large and Sparse Bifurcations Problems**

Mark Jackson, NASA/Marshall Space Flight Center; James W. Demmel and David S. Bindel, University of California, Berkeley; and *Mark J. Friedman,* University of Alabama

**3:05-3:20 Numerical Bifurcation Analysis of Lattice-Boltzmann Models**

*Kurt Lust*, K.U.Leuven, Belgium; and Pieter Van Leemput, Katholieke Universiteit Leuven, Belgium

**3:25-3:40 Bifurcations in a Differentially Heated Rotating Spherical Shell**

*Gregory M. Lewis*, The Fields Institute, Toronto, Canada; and William F. Langford, University of Guelph, Canada

Wednesday, May 28

# CP15

## Hamiltonian Models of Weak Plasma Turbulence and MHD

*2:45 PM-3:45 PM*

*Room: Magpie A*

*Chair: Alexander Wurm, University of Texas, Austin*

**2:45-3:00 From Many-Body Hamiltonian Dynamics to Kinetic Equations in Weak Plasma Turbulence**

Dominique Escande, CNRS, France; and *Yves Elskens*, CNRS-Universite de Provence, France

**3:05-3:20 Action Principle Derivation of Reduced Magneto-Fluid Models**

P.J. Morrison and *Alexander Wurm*, University of Texas, Austin

**3:25-3:40 Trapping in a Magnetic Field with Reversed Shear**

Ricardo Viana, Federal University of Paraná, Brazil; Elton Silva and *Ibere L. Caldas*, University of Sao Paulo, Brazil; and Marisa Roberto, ITA/CTA

Wednesday, May 28

# CP16

## Topics in Pattern Formation - I

*2:45 PM-3:45 PM*

*Room: Magpie B*

*Chair: Dmitri Volfson, University of California, San Diego*

**2:45-3:00 Slipping Sticks: Micromechanics of Vortex Formation in a Vibrated Layer of Granular Rods**

Lev S. Tsimring and *Dmitri Volfson*, University of California, San Diego

**3:05-3:20 Disorder in Ginzburg-Landau Systems and the Statistics of Defect Dynamics**

Hermann Riecke and *Cristian Huepe*, Northwestern University

**3:25-3:40 Anlytical Studies of the Interaction Between Turing Instabilities in Semiconductors Cavities**

*Mustapha Tlidi*, Université Libre de Bruxelles, Belgium; and John Chapman and Gregory Kozyreff, Oxford University, United Kingdom

Wednesday, May 28

# CP17

## Topics in Statistics and Time Series

*2:45 PM-3:45 PM*

*Room: Wasatch A*

*Chair: Michael B. Brimacombe, NJMS-UMDNJ*

**2:45-3:00 Statistical Considerations In The Estimation and Testing of Dynamic Biological Models in Experimental Settings**

Michael B. Brimacombe, NJMS-UMDNJ

**3:05-3:20 Synchronization-Based Parameter Estimation**

Mitrajit Dutta, University of New Hampshire

**3:25-3:40 Global Model As a Sum of Regional Models from Time Series**

Rafael M. Gutierrez and *Luis A. Sandoval*, Antonio Narino University, Columbia

Wednesday, May 28

# CP18

## Convection, Vibration, and Control

*2:45 PM-3:45 PM*

*Room: Wasatch B*

*Chair: Bassam A. Bamieh, University of California, Santa Barbara*

**2:45-3:00 Parametric Resonance in Spatially Distributed Systems**

Mihailo Jovanovic and *Bassam A. Bamieh*, University of California, Santa Barbara

**3:05-3:20 Longwave Marangoni Convection Under Heterogenous Heating**

Victor Shilov, Institute of Continuum Mechanics, Ural Branch of RAS

**3:25-3:40 Numerical Study of Double-Diffusive Free Convective Flow Past a Moving Vertical Cylinder**

Loganathan Parasuraman, Siva Subramania College of Engineering; and *Periyana G. Ganesan*, Anna University, India

Wednesday, May 28

# CP19

## Topics in Epidemics and Neural Networks

*2:45 PM-3:45 PM*

*Room: Maybird*

*Chair: Alexander C. Roxin, Northwestern University*

**2:45-3:00 Self-Sustained Activity in a Network of Excitable Neurons with Local and Global Connectivity**

Hermann Riecke, Sara Solla, and *Alexander C. Roxin*, Northwestern University

**3:05-3:20 A Spatial/Temporal Landscape Paradigm for Epidemic Simulation**

Leon M. Arriola, University of Wisconsin, Whitewater

**3:25-3:40 Lyapunov Functions for Compartmental Epidemic Models**

Andrei Korobeinikov, University of Oxford, United Kingdom

Wednesday, May 28

# CP20

## Synchronization in Networks of Oscillators

*2:45 PM-3:45 PM*

*Room: Superior A*

*Chair: Louis M. Pecora, Naval Research Laboratory*

**2:45-3:00 Synchronization Stability and Patterns in Scale-Free Networks of Oscillators**

Louis M. Pecora, Naval Research Laboratory

**3:05-3:20 Synchronization and Total Phase Locking of Mutually Coupled Oscillators**

Dirk Aeyels and *Jonathan A. Rogge*, Ghent University, Belgium

**3:25-3:40 Rings of Oscillators with Delayed Coupling**

Sue Ann Campbell, University of Waterloo, Canada

Wednesday, May 28

# CP21

## Nonlinear Dynamics in Lasers

*2:45 PM-3:25 PM*

*Room: Superior B*

*Chair: Thomas W. Carr, Southern Methodist University*

**2:45-3:00 Pulse Dynamics in a Laser with Delayed Feedback**

Thomas W. Carr, Southern Methodist University

**3:05-3:20 Extensive and Non-Extensive Spatiotemporal Chaos in a Laser**

Jerome Plumecoq, Marc Lefranc, Dominique Derozier, and *Serge Bielawski*, PHLAM/Université Lille I, France; and Christophe Szwaj, PHLAM - Universite de Lille, France

Wednesday, May 28

## CP22

### Topics in Neuroscience - I

*2:45 PM-3:25 PM*

*Room: White Pine*

*Chair: Kim Montgomery, Northwestern University*

**2:45-3:00 Bifurcation Analysis of Amplification and Tuning Mechanisms of Auditory Hair Cells**

Mary C. Silber, Sara Solla, and *Kim Montgomery*, Northwestern University

**3:05-3:25 Oscillatory Neural Model of Cognitive Functions: Feature Representation and Binding, Selective Attention, Memorisation and Novelty Detection**

*Roman M. Borisyuk*, University of Plymouth, United Kingdom; and Yakov Kazanovich, Institute of Mathematical Problems in Biology, Russia

**3:25-3:40 Mesoscopic Neurodynamics: The Transition to a New Equilibrium**

Evan Haskell, University of Utah

## Coffee Break

*3:45 PM-4:15 PM*

*Room: Golden Cliff*

Wednesday, May 28

## MS35 (For Part I, see MS9)

### Applications of Difference Equations II

*4:15 PM-6:45 PM*

*Room: Superior A*

Difference equations have had a tremendous impact of the development of dynamical systems. Indeed, the logistic map studied by Robert May in 1974, was one of the first instances of chaos found. Another well known example is the Henon map, which is not yet fully understood. Difference equations are particularly good tools for studying population dynamics and, more recently, with the work of Cushing and his coauthors, some aspects of ecology.

**Organizer: Judy A. Kennedy**
*University of Delaware*

**4:15-4:40 Generalized Henon Difference Equations with Delay**

James A. Yorke, University of Maryland, College Park; and *Judy A. Kennedy*, University of Delaware

**4:45-5:10 Attractors for Discrete, Periodic Dynamical Systems and Applications to Models in Population Biology**

James Roberds, USDA Forest Service; and John E. Franke and *James F. Selgrade*, North Carolina State University

**5:15-5:40 Periodic Dynamical Systems in Genetics and Population Models**

Abdul-Aziz Yakubu, Howard University; and *John E. Franke*, North Carolina State University

**5:45-6:10 Probabilities of Extinction, Weak Extinction, Permanence and Mutual Exclusion in a Discrete Lotka-Volterra Model with an Invading Species**

David Chan, North Carolina State University

**6:15-6:40 Chaotic Transients in Maps from Biological Population Models**

Andy Foster, Memorial University, Newfoundland, Canada

Wednesday, May 28

## MS36

### The Biophysics of Molecular Motors and Cell Motility

*4:15 PM-7:15 PM*

*Room: Ballroom I*

Biological cells can use the free energy stored in chemical bonds or electrochemical gradients to produce directed motion. The molecular mechanisms responsible for this energy transduction are still not clear. This minsymposium will highlight several computational and theoretical investigations of force generation in motor protein function and cell motility.

**Organizer: Timothy C. Elston**
*University of North Carolina, Chapel Hill*

**4:15-4:40 Cytoskeletal Mechanics and Spindle Morphogenesis During mitosis in Drosophila Embryos**

Eric N. Cytrynbaum, University of California, Davis

**4:45-5:10 Force Generation by the Growth of Branched Actin Networks**

A. E. Carlsson, Washington University, St. Louis

**5:15-5:40 Large-scale Conformational Changes in Motor Proteins**

Todd Minehardt, University of Colorado, Denver

**5:45-6:10 Energy Flow and Efficiencies of Molecular Motors**

Hongyun Wang, University of California, Santa Cruz

Wednesday, May 28

# MS37

## Defects in Experiment and Theory

*4:15 PM-6:45 PM*

*Room: Ballroom II*

Defects play an important role in the evolution of patterns: some defects actively generate patterns, others are formed as passive interfaces between competing patterns. Sources in 1d as well as target patterns and spiral waves in 2d are examples for active defects. Homoclons, contact defects, vortices and shock-like structures such as sinks arise as passive defects in 1d and 2d. This minisymposium brings together experimentalists, working on chemical and hydrothermal waves, and applied mathematicians who work on defects from different viewpoints using techniques such as asymptotic matching, spatial dynamics and amplitude equations.

**Organizer: Arnd Scheel**
*University of Minnesota, Minneapolis*

**Organizer: Bjorn Sandstede**
*Ohio State University*

**4:15-4:40 Wave Propagation and Defect Dynamics in Excitable Systems with Anomalous Dispersion**
Oliver Steinbock, University of Warwick, United Kingdom/Florida State University

**4:45-5:10 Polymer Flow Instabilities: From Amplitude Equations to Turbulence?**
Wim van Saarloos, Leiden University, Netherlands

**5:15-5:40 Traveling Hole Solutions of the Complex Ginzburg-Landau Equation**
Joceline Lega, University of Arizona

**5:45-6:10 Spiral Spectra**
Dwight Barkley, University of Warwick, United Kingdom

**6:15-6:40 Defects in Oscillatory Media - Towards a Classification**
Arnd Scheel, University of Minnesota, Minneapolis

Wednesday, May 28

# MS38 (For Part II, see MS 62)

(For Part II, see MS 62)

## Discrete Geometry and Geometric Integration

*4:15 PM-7:15 PM*

*Room: Ballroom III*

Continuous systems may have various geometric and invariant properties, such as energy and momentum conservation, as well as symplecticity, and it is desirable for numerical simulations to preserve these invariants whenever possible.

Geometric integration is concerned with the development and analysis of such structure-preserving discretizations, and further advances in the field are facilitated by a thorough understanding of the geometry of the discretized system.

This minisymposium will review some recent advances in geometric integration as well as efforts to understand geometry at an intrinsically discrete level. It will also serve to enhance the interaction between these two mutually complementary fields.

**Organizer: Claudia Wulff**
*University of Surrey, United Kingdom*

**Organizer: Jerrold E. Marsden**
*California Institute of Technology*

**Organizer: Melvin Leok**
*California Institute of Technology*

**4:15-4:40 Introduction to Discrete Geometry and Geometric Integration**
Jerrold E. Marsden, California Institute of Technology

**4:45-5:10 Approximate Momentum Conservation for Spatial Semidiscretizations of Nonlinear Wave Equations**
*Claudia Wulff*, University of Surrey, United Kingdom; and Marcel Oliver, International University Bremen, Germany

**5:15-5:40 Discrete Exterior Calculus - Part I**
Jerrold E. Marsden, Anil Hirani, and *Melvin Leok*, California Institute of Technology; and Mathieu Desbrun, University of Southern California

**5:45-6:10 Discrete Exterior Calculus - Part II**
Jerrold E. Marsden, Melvin Leok, and *Anil Hirani*, California Institute of Technology; and Mathieu Desbrun, University of Southern California

*MS 38, continued*

**6:15-6:40 Reversible Methods for Collisional Dynamics with Applications in Statistical Mechanics**
*Stephen Bond*, University of California, San Diego; and Ben Leimkuhler, University of Leicester, United Kingdom

**6:45-7:10 Approximation of the Matrix Exponential by Lie-group Techniques**

Antonella Zanna, University of Bergen, Norway

Wednesday, May 28

# MS39

## Dynamics of Discrete Vortices

*4:15 PM-7:15 PM*

*Room: Magpie A*

Discrete vortex models are derived from the governing equations of fluid flow by assuming the vorticity distribution to be singular, or near-singular in some way. They have played a significant role in the modeling and understanding of fluid flows, from the von Karman vortex street picture of the wake of a cylinder, to the localized induction approximation for vortex filaments. This minisymposium, dedicated to the memory and work of Richard Pelz, will highlight recent work which uses discrete vortex models in a wide range of applications, including the modeling of wakes and shear layers, flows on a sphere, and turbulence modeling.

**Organizer: Hassan Aref**
*University of Illinois, Urbana-Champaign*

**Organizer: Paul K. Newton**
*University of Southern California*

### 4:15-4:40 Vortex Buckyballs and Other Particle Clustering Patterns Far from Equilibrium

Paul K. Newton, University of Southern California

### 4:45-5:10 Point Vortex Models for Wakes and Shear Layers

Hassan Aref, University of Illinois, Urbana-Champaign

### 5:15-5:40 Vortex Models of Inertial Range Turbulence

Anthony Leonard, California Institute of Technology

### 5:45-6:10 Topological Analysis of Point Vortex Dynamics

Philip Boyland, University of Florida

### 6:15-6:40 Monte-Carlo and Polyhedra Based Algorithms for Extremal Energy States in the Vortex N-body Problem

Chjan C. Lim, Rensselaer Polytechnic Institute

### 6:45-7:10 Vortex Lattice Dynamics

Mark A. Stremler, Vanderbilt University

Wednesday, May 28

# MS40

## Dynamics of Semiconductor Lasers Subject to Delay

*4:15 PM-7:15 PM*

*Room: Magpie B*

Semiconductor lasers are widely used nowadays in practical applications, such as optical data storage and optical communication. It is known that even small amounts of optical feedback, e.g. from reflections or in mutually coupled lasers, can have a very large impact on the dynamics. Mathematically, such laser systems are decribed by delay differential equations (DDEs) with a fixed delay, and they have emerged as an ideal area of application for new methods for DDEs, in particular numerical continuation. In a fruitful interplay between theory and application, new methods are being developed and used with success to better understand the dynamics of laser systems. The speakers in this minisymposium will demonstrate this by presenting recent results in this field.

**Organizer: Bernd Krauskopf**
*University of Bristol, United Kingdom*

**Organizer: Vivi Rottschafer**
*University of Leiden, The Netherlands*

### 4:15-4:40 Computation of Connecting Orbits in Delay Differential Equations

Dirk Roose, Koen Engelborghs, and *Giovanni Samaey*, Katholieke Universiteit Leuven, Belgium

### 4:45-5:10 A Two-parameter Study Near the Locking Range of a Semiconductor Laser with Phase-conjugate Feedback

Bernd Krauskopf and *Kirk Green*, University of Bristol, United Kingdom

### 5:15-5:40 Delay Dynamics of Diode Lasers with Short External Cavities

*Athanasios Gavrielides*, Air Force Research Laboratory; and Tilmann Heil and Ingo Fischer, Technische Universität Darmstadt, Germany

### 5:45-6:10 Stability Analysis of External Cavity Modes in the Lang-Kobayashi Equations

*Vivi Rottschafer,* University of Leiden, The Netherlands; and Bernd Krauskopf, University of Bristol, United Kingdom

*MS 40, continued*

### 6:15-6:40 Bifurcation Bridges in Lasers Subject to Optical Feedback

Thomas Erneux, Université Libre de Bruxelles

### 6:45-7:10 Dynamics of Multi-Section Lasers

Jan Sieber, University of Bristol, United Kingdom

Wednesday, May 28

# MS41

## Nonlinear Tides in Coastal Basins

*4:15 PM-7:15 PM*

*Room: Wasatch A*

Tides exist all over the world, but obtain prominence only at the ocean's margins due to resonance with eigenfrequencies of coastal basins. While tides are first of all experienced as a very regular, periodic phenomenon, certain basic aspects of tidal dynamics (related to geometry of the basin and nonlinearity of the governing equations) may locally provoke a nonlinear response. This nonlinearity may be particularly evident in the tidal current structure, which is of importance to the flushing and mixing of the near-coastal environment. In this session we will address the nonlinear dynamics of tides in coastal embayments from several points of view, including its observational and experimental aspects.

**Organizer: Huib de Swart**
*Utrecht University, The Netherlands*

**Organizer: Arjen Doelman**
*University of Amsterdam, Netherlands*

**4:15-4:40 Analysis and Prediction of Nonlinear, Nonstationary Coastal Water Levels**
Ted Frison, Chaotic.com

**4:45-5:10 Non-Stationary Tidal Processes in Estuaries**
David Jay, Oregon Health & Science University

**5:15-5:40 Tide-topography Interaction and Morphologic Pattern Formation**
Huib de Swart, Utrecht University, The Netherlands

**5:45-6:10 Dynamics of the Storm Gates for Protecting Venice Lagoon**
Chiang Mei, Massachusetts Institute of Technology

**6:15-6:40 A Weakly Nonlinear Approach to Complex Tidal Dynamics**
Arjen Doelman, University of Amsterdam, Netherlands

**6:45-7:10 Nonlinear Response of a Co-oscillating Tidal Basin; Theory and Laboratory Experiments**
Guido M. Terra, University of Amsterdam/Royal Netherlands Institute for Sea Research (NIOZ), Netherlands

Wednesday, May 28

# MS42 (For Part II, see MS 66)

## Pattern Formation through Nonlocal Interactions

*4:15 PM-7:15 PM*

*Room: Maybird*

In many physical systems, nonlocal interactions play a crucial role in pattern formation. Such nonlocal interactions can range from long-range connections between elements of a system, to competition for resources among elements, to the presence of global signaling agents. These show up in a wide variety of applications, from vision and other neuroscience arenas, to materials science, to propagation of activity in biological or chemical excitable media. The goal of this minisymposium is to survey both the types of mathematical techniques being used to handle nonlocal problems and the range of physical situations in which they arise.

**Organizer: Jonathan E. Rubin**
*University of Pittsburgh*

**Organizer: William Troy**
*University of Pittsburgh*

**4:15-4:40 Spatial Patterns Rising in Cancer Models**
Avner Friedman, The Ohio State University

**4:45-5:10 Multi-Bumps in Two Dimensional Nonlocal Problems**
Carlo R. Laing, Massey University, New Zealand; and *William Troy*, University of Pittsburgh

**5:15-5:40 The Visual Cortex as a Crystal**
*Paul C. Bressloff*, University of Utah; and Jack D. Cowan, University of Chicago

**5:45-6:10 Cortical Architecture and Patterns of Response in the Primary Visual Cortex**
David W. McLaughlin, Courant Institute of Mathematical Sciences, New York University

**6:15-6:40 Nonlinear Coupling Near a Subcritical Hopf Bifurcation**
Jonathan Drover, University of Pittsburgh

Wednesday, May 28

# MS43 (For Part I, see MS22)

## Simulation and Modeling of Multi-Scale Fluid Motion and Turbulence

*4:15 PM-7:15 PM*

*Room: Superior B*

This minisymosium will focus on recently developed techniques for the modeling and simulation of fluid flow wherein so many spatial (and/or time) scales are activated as to make computational approximation prohibitively expensive. Issues to be addressed include (1) turbulence modeling for both compressible and incompressible flow founded upon the Lagrangian averaging framework, wherein variational methods are combined with G.I. Taylor's frozen turbulence hypothesis to produce closed models of large-scale flow, (2) atmospheric flows wherein inertia-gravity waves caused by rotation are removed using variational asymptotics, (3) new PDE techniques involving degenerate parabolic equations, and (4) atomostic and continuum simulation of nano-fluidics.

**Organizer: Steve Shkoller**
*University of California, Davis*

**Organizer: Darryl Holm**
*Los Alamos National Laboratory*

**4:15-4:40 On the Leray Model of Turbulence**
Edriss S. Titi, University of California, Irvine and Weizman Institute of Science, Israel

**4:45-5:10 The Scaling Structure of Velocity Statistics at High Reynolds Numbers**
Susan Kurien, Los Alamos National Laboratory

**5:15-5:40 Regularization Modeling of Rotating Turbulence**
Bernard Geurts, University of Twente, Netherlands

**5:45-6:10 New Approaches in Modeling GFD Turbulence**
Balasubramanya Nadiga, Los Alamos National Laboratory

**6:15-6:40 Is There Universality in the Presence of Waves: The Case of Magnetohydrodynamic Turbulence**
Annick Pouquet, NCAR

Wednesday, May 28

# MS44

## Swarming in Biological and Multi-Agent Systems

*4:15 PM-7:15 PM*

*Room: Wasatch B*

A commonly observed natural phenomenon is the cohesive movement of a biological population. This so-called swarming behavior may arise naturally from social interactions between individuals. The first half of this session will address the biology, modeling, and analysis of swarming populations.

In such populations, the pairwise interactions between organisms and the global dynamics of the swarm can be intimately related. The second half of this session will examine applications of swarming behaviors to multi-agent systems. The focus is on engineering some desired behavior by an appropriate choice of interaction rules. These artificial swarms are useful to problems currently under consideration in defense and industry.

**Organizer: Chad M. Topaz**
*Duke University*

**Organizer: Daniel Marthaler**
*Duke University*

**4:15-4:40 Neighbor to Neighbor: Relating Individual to Group Behaviors in Schooling Fish**
Julia Parrish, University of Washington, Seattle; *Daniel Grunbaum*, University of Washington; and Steven Viscido, SAFS, University of Washington

**4:45-5:10 Discrete and Continous Models of Fish Populations**
Bjorn Birnir, University of California, Santa Barbara

**5:15-5:40 Dynamics of a Two-dimensional Continuum Model for Swarming**
Andrea L. Bertozzi and *Chad M. Topaz*, Duke University

**5:45-6:10 Geometry of Steering Laws in Cooperative Control**
P.S. Krishnaprasad, University of Maryland, College Park

**6:15-6:40 Abstractions and Control Policies for a Group of Vehicles**
Calin Belta, Guilherme Pereira, and *Vijay Kumar*, University of Pennsylvania

**6:45-7:10 Collective Motion Algorithms for Determining Environmental Boundaries**
Daniel Marthaler, Duke University

Wednesday, May 28

# MS45 (For Part I, see MS23)

## Synchrony in Neuroscience

*4:15 PM-7:15 PM*

*Room: White Pine*

Oscillations generated by the synchronous activity of networks of neurons are believed to play a fundamental role in neuronal processing. Dynamical systems theory has been very successful in analyzing and understanding synchronous behavior in models of such networks. This symposium will focus on recent theoretical and experimental results on synchronized behavior in neuronal networks with an emphasis on the role dynamical systems theory in modeling and experimental research. The questions addressed will include the role of noise and network architecture in the generation of synchronous behavior, and extension of results on small networks to networks of many neurons.

**Organizer: Kresimir Josic**
*University of Houston*

**Organizer: Stefano Boccaletti**
*Istituto Nazionale di Ottica Applicata, Italy*

**4:15-4:40 Slow and Fast Inhibition Interact to Create a Theta Rhythm in CA1**
Nancy J. Kopell and *Horacio Rotstein*, Boston University

**4:45-5:10 Cortical Information Encoded Jointly by Random and Pattern Spike Trains**
Ruedi Stoop, Institute of Neuroinformatics ETHZ/UNIZH, Switzerland

**5:15-5:40 Patterns of Synchrony in Coupled Cell Networks**
Ian Stewart, University of Warwick, United Kingdom; and *Martin Golubitsky*, University of Houston

**5:45-6:10 Dynamics of Delayed, Paired Excitatory-inhibitory Neural Feedback**
Andre Longtin, University of Ottawa, Canada; and *Carlo R. Laing*, Massey University, New Zealand

**6:15-6:40 Cooperative Effects of Noise in Homoclinic Chaotic Systems**
Riccardo Meucci, F. Tito Arecchi, Enrico Allaria, and *Stefano Boccaletti*, Istituto Nazionale di Ottica Applicata, Italy; and Juergen Kurths and Chansong Zhou, Universität Potsdam, Germany

*MS 45 continued*

**6:45-7:10 Development of Deep Brain Stimulation Techniques with Stochastic Phase Resetting Methods**
Peter A. Tass, Institute of Medicine (MEG), Germany

# Dinner Break

*7:15 PM-8:30 PM*

*Attendees on Their Own*

# SIAG/DS Business Meeting

*8:30 PM-9:30 PM*

*Room: Ballroom II*

# Thursday, May 29

## Game Room

*8:00 AM-12:00 AM*

*Room: Eagles Nest*

## Registration

*8:00 AM-4:30 PM*

*Room: Ballroom Lobby*

Thursday, May 29

# MS46

## Analysis of Spatially Extended Synaptic Neural Networks

*8:30 AM-10:30 AM*

*Room: Ballroom I*

Analyzing activity dynamics within spatially extended synaptic networks is important for understanding a wide range of both natural and pathological brain functions such as sensory processing and epileptic seizures. Unlike activity in individual neurons, mediated mostly by diffusion, activity in extended synaptic networks entail non-local and patterned interactions that are best represented by sets of integral or integrodifferential equations. The focus of this minisymposium is to explore recent attempts to analyze the equations that arise in the study of extended neural systems and to apply that analysis toward understanding specific brain functions.

**Organizer: David J. Pinto**
*Brown University*

**8:30-8:55 Analysis of Traveling Pulses in a Continuous Synaptic Network**
David J. Pinto, Brown University

**9:00-9:25 Multiple-spike Waves in One-dimensional Integrate-and-fire Neural Networks**
Remus Osan, Princeton University

**9:30-9:55 Wave Propagation in Periodically Modulated Cortical Media**
Paul C. Bressloff and *Stefanos Folias*, University of Utah

**10:00-10:25 The Simple and the Complex of Feature Selectivity in V1**
Louis Tao, Courant Institute of Mathematical Sciences, New York University

Thursday, May 29

# MS47

## Control of Chaos and Low Energy Transfers in Spacecraft Guidance

*8:30 AM-10:30 AM*

*Room: Ballroom II*

Significant results were already achieved in the guidence of spacecrafts by using the characteristics of the chaotic systems. The space agency NASA, in 1987, made use of the sensitive dependence on initial conditions in the classical three-body problem to maneuver ISEE-3 spacecraft towards a comet by means of small correction, which requires only a small amount of fuel. Later, the spacecraft Hiten was sent to the Moon by using balistic lunar capture transfer that was accomplished by the use of regions of chaotic motion in the phase space. In this minisymposium we present a unify view that integrates these low energy transfer approaches and the paradigm of control of the chaos, showing the advantages of this unify approach.

**Organizer: Elbert E. Macau**
*LIT - Laboratory of Integration and Testing INPE - Brazilian Institute for Space Research, Brazil*

**Organizer: Celso Grebogi**
*Universidade de Sao Paulo/USP, Brazil*

**8:30-8:55 Uncertainty and Effective Dimension in Astrophysics**
*Alessandro Moura*, Universidade de Sao Paulo, Brazil; and Celso Grebogi, Universidade de Sao Paulo/USP, Brazil

**9:00-9:25 Chaos Associated to Weak Capture and Low Energy Transfers**
Edward Belbruno, Princeton University

**9:30-9:55 Exploiting Unstable Periodic Orbits of a Chaotic Invariant Set for Spacecraft Control**
Elbert E. Macau, LIT - Laboratory of Integration and Testing INPE - Brazilian Institute for Space Research, Brazil

**10:00-10:25 On the History of the Slingshot Effect and Cometary Orbits**
*Roger Broucke*, University of Texas, Austin; and Antonio Prado, Brazilian National Institute for Space Research - INPE, Brazil

Thursday, May 29

# MS48

## Dynamics of Thin Liquid Films

### *8:30 AM-10:30 AM*

*Room: Ballroom III*

Thin liquid films occur in many settings, including a variety of industrial coating processes, in lubrication, soap films, etc. The modeling of thin films typically involves partial differential equations that include higher order derivatives due to contributions of surface tension, and nonlinearities due either to approximations such as the lubrication approximation, or to nonlinear constitutive behavior of the fluid. Recent activity in this field has uncovered new physical phenomena, and new mathematics to help understand the behavior of thin films. In this minisymposium, speakers will address topics from the theory of PDE models, their numerical simulation, and applications.

**Organizer: Robert P. Behringer**
*Duke University*

**Organizer: Michael Shearer**
*North Carolina State University*

**8:30-8:55 Drop Pinch-off and Filament Dynamics of Wormlike Micellar Fluids**
*Linda Smolka*, Duke University and Pennsylvania State University; and Andrew Belmonte, Pennsylvania State University

**9:00-9:25 The Dynamics of Nematic Polymers in Laminar Flows: A Zoo of Bifurcations Associated with Bulk Molecular Phase Transitions**
Greg Forest, University of North Carolina, Chapel Hill

**9:30-9:55 Nonlinear Instability of Contact Lines in Thin Film Flows Driven by Marangoni Forces**
Andrea L. Bertozzi, Thomas P. Witelski, Robert Behringer, and *Jeanman Sur*, Duke University

**10:00-10:25 Comparisons Between Models of Dynamic Contact Lines**
Michael Shearer and *Rachel Levy*, North Carolina State University

Thursday, May 29

# MS49

## Feedback Mechanisms in Intra-Cellular Dynamics

### *8:30 AM-10:30 AM*

*Room: Magpie A*

Feedback mechanism play a central role in intra-cellular dynamics. They serve for robustness, control and efficiency of cellular behavior. This Minisyposium will explore theoretical aspects of feedback mechanisms due to Bode's integral formula and will exemplify them by mathematical analysis based on measured data of three biological systems. Feedback in the signalling cascade of the TNF receptor is demonstrated to lead to robustness of the system. For the phosphotransferase system in bacterial metabolism it is shown how feedback leads to control. For the JAK-STAT signalling pathway of the Epo receptor, feedback is demonstrated to enable efficient signal transduction.

**Organizer: Jens Timmer**
*University of Freiburg, Germany*

**Organizer: Birgit Schoeberl**
*Massachusetts Institute of Technology*

**8:30-8:55 Bode's Integral Formula as a Conservation of Fragility Law for Feedback Systems**
Tau-Mu Yi, California Institute of Technology

**9:00-9:25 The Apoptotic Decision in TNF-treated Cells: Combining Experimental and Mechanistic Modeling Approaches**
Douglas Lauffenburger, John Albeck, Peter Sorger, Birgit Schoeberl, and *Suzanne Gaudet*, Massachusetts Institute of Technology

**9:30-9:55 Feedback and Control in the Metabolism of E. Coli**
Thomas Sauter, Ernst Dieter Gilles, Holger Conzelmann, Frank Allgöwer, and *Eric C. Bullinger,* University of Stuttgart, Germany

**10:00-10:25 Feedback as a Remote Sensor in Cellular Signal Transduction**
Thorsten Müller and *Jens Timmer*, University of Freiburg, Germany; Olivier Sandra, INRA - Unite de Physiologie Animale, France; Ursula Klingmüller, Max Planck Institute for Immunebiology; and Ira Swameye, Max Planck Institute for Immunebiology, Germany

Thursday, May 29

# MS50

## Pattern Formation in the Presence of Feedback

### *8:30 AM-10:30 AM*

*Room: Magpie B*

Spatio-temporal feedback may be used to probe the nonlinear pattern formation process, to control pattern formation, and as a mechanism to alter fundamentally the patterns exhibited by a system. This minisymposium brings together results of experiments, mathematical modeling and analysis of various pattern forming systems subjected to feedback, with a focus on local rather than global feedback. Applications to catalytic surface reactions, excitable reaction-diffusion systems, falling thin liquid films, and traveling wave solutions to the complex Ginzburg-Landau equation will be featured. The research challenges and open questions for this emerging field of pattern formation investigation will be highlighted.

**Organizer: Mary C. Silber**
*Northwestern University*

**Organizer: Anna L. Lin**
*Duke University*

**8:30-8:55 Spatiotemporal Dynamics and Control of Thin Liquid Films: Experiments and Theory**
Michael Schatz and *Roman Grigoriev*, Georgia Institute of Technology; and Nicolas Garnier, CNRS Ecole Normale Superieur de Lyon, France

**9:00-9:25 Spatiotemporal Addressing of Surface Activity**
Harm Hinrich Rotermund and Janpeter Wolff, Fritz-Haber Institut, MPG, Germany; *Yannis Kevrekidis*, Princeton University; and Athanasios Papathanasiou, Fritz-Haber Institut, Germany

**9:30-9:55 Feedback Stabilization and Control of Unstable Propagating Waves**
Tatsunari Sakurai, Ube National College of Technology, Japan; and Eugene Mihaliuk, Florin Chirila, and *Kenneth Showalter*, West Virginia University

**10:00-10:25 Spatial and Temporal Feedback Control of Benjamin-Feir Unstable Traveling Waves**
Kim Montgomery and *Mary C. Silber*, Northwestern University

Thursday, May 29

# MS51

## Patterns and Dynamics in Combustion

*8:30 AM-10:30 AM*

*Room: Wasatch A*

Combustion, like many other areas of application, exhibits highly interesting pattern formation and dynamics. This minisymposium features talks in both gaseous and solid fuel combustion, including descriptions of both theoretical and experimental research.

**Organizer: Alexander A. Golovin**
*Northwestern University*

**Organizer: Bernard Matkowsky**
*Northwestern University*

**8:30-8:55 Spiral Waves in Sequential Flames**
Alexander A. Golovin, Northwestern University

**9:00-9:25 Spatiotemporal Patterns and Dynamics of Hot Spots in Solid Fuel Combustion**
Alvin Bayliss and Bernard Matkowsky, Northwestern University

**9:30-9:55 Counter-propagating Fronts in Pulsating Flames on an Annular Burner**
Michael Gorman, University of Houston

**10:00-10:25 Long-wave Dynamics of Flames Governed by Coupled Burgers Equations**
Alexander A. Golovin, Northwestern University; and Eugenia Glasman and *Alexander Nepomnyashchy*, Technion - Israel Institute of Technology, Israel

Thursday, May 29

# MS52 (For Part II, see MS77)

## PDE Methods in Multi-scale Flows

*8:30 AM-10:30 AM*

*Room: Superior A*

In recent years there has been a significant interest by the applied mathematical community in rigorous and PDE approach to multi-scale flows. In this mini-symposium the speakers will present their recent analytical and computational results concerning the global well-posedness, regularity, dynamical and statistical properties of solutions to this type of flows.

**Organizer: Edriss S. Titi**
*University of California, Irvine and Weizman Institute of Science, Israel*

**Organizer: Peter Constantin**
*University of Chicago*

**8:30-8:55 Regularity Results for Some Geophysical Models**
Mohammed B. Ziane, University of Southern California

**9:00-9:25 Rigorous Characterization of Boundary Layer Separations of 2D Incompressible Flows and its Applications to Geophysical Fluid Dynamics**
Shouhong Wang, Indiana University

**9:30-9:55 A Perspective for Rigorous Large Scale Simulations of Turbulent Premixed Flames**
Boualem Khouider, Courant Institute of Mathematical Sciences, New York University

**10:00-10:25 Propagation of Waves in a Turbulent Medium**
Knut Solna, University of California, Irvine

Thursday, May 29

# MS53 (For Part II, see MS 100)

## Renormalization Group and Asymptotics for Differential Equations

*8:30 AM-10:30 AM*

*Room: Superior B*

Perturbation theory and asymptotic analysis play a fundamental role in applied mathematics and dynamical systems theory. Familiar techniques for ordinary differential equations include the method of multiple scales, averaging theory, asymptotic matching, center manifold theory, and WKB, just to name a few. In the last decade, the renormalization group method was proposed as a unified framework for singular and reductive perturbation problems. The RG method improves the global behavior of ``naive" perturbation expansions by renormalizing secular divergences. This minisymposium focuses on recent developments of RG, as well as its theoretical underpinnings and applications.

**Organizer: Anthony Harkin**
*Harvard University*

**8:30-8:55 Renormalization Group Approach to Differential Equation Problems**
Yoshi Oono, University of Illinois, Urbana-Champaign

**9:00-9:25 Geometrical Formulation of the Renormalization-Group Method with Application to Transport and Stochastic Equations**
Teiji Kunihiro, Kyoto University, Japan

**9:30-9:55 Title not available at time of publication**
Mohammed B. Ziane, University of Southern California

**10:00-10:25 Symplecticity Preserving Renormalization Group Method**
Shin-ichirou Gotou, Nagoya University, Japan

Thursday, May 29

# MS54 (For Part I, see MS 32)

## Stochastic Modeling and Statistical Description of Spatially Extended Nonlinear Dynamics

*8:30 AM-10:30 AM*

*Room: Maybird*

Many systems involve such complicated chaotic dynamics over a wide range of spatiotemporal scales that they can be naturally described by statistical methods rather than detailed description of individual trajectories. In this minisymposium we will present several interdisciplinary problems and discuss modern theoretical and numerical approaches in characterizing their statistical properties. In particular, we will present new results on the equilibrium statistical mechanics for truncated analogs of conservative PDE's, statistical long time dynamics of nonlinear deterministic and stochastic differential equations, and stochastic mode-reduction in systems with separation of time scales.

**Organizer: Gregor Kovacic**
*Rensselaer Polytechnic Institute*

**Organizer: Ilya Timofeyev**
*University of Houston*

**8:30-8:55 Stochastic Mode-Reduction in Under-Resolved Systems**
Andrew Majda and *Eric Vanden Eijnden,* Courant Institute of Mathematical Sciences, New York University; and Ilya Timofeyev, University of Houston

**9:00-9:25 Effective Modeling in Complex Microfluid Systems**
*Peter R. Kramer*, Rensselaer Polytechnic Institute; and Andrew Majda, Courant Institute of Mathematical Sciences, New York University

**9:30-9:55 Mean Field Descriptions of BEC: An Experimental Playground for Nonlinear Waves**
Panayotis Kevrekidis, University of Massachusetts, Amherst

**10:00-10:25 Bubble Interaction in the Stochastic Cahn-Hilliard Equation**
Ibrahim Fatkullin, Institute for Advanced Study, School of Mathematics

Thursday, May 29

# MS55 (For Part II, see MS 78)

## Topological Methods in Dynamics

*8:30 AM-10:30 AM*

*Room: White Pine*

Dynamics which are genuinely nonlinear demand mathematical methods which are likewise nonlinear. Topological methods offer global results, robustness under large perturbations, and, increasingly, computability. This 2-part minisymposium features a broad collection of topological methods, with specific applications to, among others, elliptic and parabolic PDEs, fluid dynamics, and celestial mechanics. Since topological methods usually have high "overhead" in terms of learning the background mathematics (homology theory, symplectic topology, etc.), it is especially important to have a forum where the curious non-specialist can witness the state of the art.

**Organizer: Robert W. Ghrist**
*University of Illinois, Urbana-Champaign*

**Organizer: Konstantin Mischaikow**
*Georgia Institute of Technology*

**8:30-8:55 Geometric Realization of Pisot Tiling Spaces**
Jarek Kwapisz, Montana State University

**9:00-9:25 Isolating Blocks for the Three-Body Problem**
Rick Moeckel, University of Minnesota, Minneapolis

**9:30-9:55 Recent Results in the Theory of Compact Minimal Flows**
Alica Miller, University of Illinois, Urbana-Champaign

**10:00-10:25 Generic Hydrodynamic Instability via Contact Homology**
*Robert W. Ghrist*, University of Illinois, Urbana-Champaign; and John Etnyre, University of Pennsylvania

Thursday, May 29

# MS56

## Using Synchronization for Signal Analysis

*8:30 AM-10:30 AM*

*Room: Wastach B*

Many researchers have applied methods from nonlinear time series analysis for investigating synchronizing dynamical systems. However, it is also possible to use synchronization as a tool for time series analysis. Synchronization based methods are interesting alternatives for typical signal analysis tasks such as signal classification, parameter estimation or time series prediction. Furthermore, such methods may be considered as building blocks of dynamical information processing systems with potential relevance for understanding brain dynamics.

**Organizer: Ulrich Parlitz**
*University of Goettingen, Germany*

**8:30-8:55 Tuning Chaotic Synchronization for Application in Temporal Pattern Recognition**
Martin Hasler and *Oscar De Feo*, Swiss Federal Institute of Technology-Lausanne, Switzerland

**9:00-9:25 Using Generalized Synchronization for Modelling and Prediction of Time Series**
Ulrich Parlitz and *Alexander Hornstein*, University of Goettingen, Germany

**9:30-9:55 Synchronization vs Linear Filtering for Extracting Phase Information of Oscillations of Unknown Origin from Noisy Time Series**
Axel Rossberg, University of Freiburg, Germany

**10:00-10:25 Probabilistic Approach for Designing Synchronizing Dynamical Systems for Parameter Estimation**
Ulrich Parlitz and Jochen Broecker, University of Goettingen, Germany

# Coffee Break

*10:30 AM-11:00 AM*

*Room: Golden Cliff*

Thursday, May 29

# IP5

## Schooling by Design: Coordinated Multi-Vehicle Dynamics

*11:00 AM-12:00 PM*

*Room: Ballroom*

*Chair: Jerrold E. Marsden, California Institute of Technology*

A school of fish exhibits remarkable emergent behaviors: it maneuvers swiftly, it evades predators and it forages successfully. Biologists are developing models that can reproduce school behaviors with simple traffic rules for individual fish. Our aim is similar but our problem is different: to design coordinated dynamics for a network of autonomous vehicles. The vehicle network will serve as a reconfigurable sensor array capable of efficient search and discovery. Because our prescribed traffic rules will be implemented on real vehicles, we must guarantee stability, scalability and robustness of the schooling dynamics. Our techniques make use of artificial potentials, virtual bodies, symmetry and reduction. In a current application, we are designing coordinated dynamics for a fleet of underwater gliders that will be deployed in Monterey Bay as part of an autonomous ocean sampling network.

**Naomi Ehrich Leonard**
*Princeton University*

# Lunch Break

*12:00 PM-1:30 PM*

*Attendees on Their Own*

Thursday, May 29

# IP6

## Dynamical Systems and the Navier-Stokes Equations

*1:30 PM-2:30 PM*

*Room: Ballroom*

*Chair: Peter Constantin, University of Chicago*

The Navier-Stokes equations are a system of nonlinear, partial differential equations which describe the motion of a viscous, incompressible fluid. I will describe an approach based on ideas from dynamical systems theory to understand the long time behavior of solutions of these equations. For systems of ordinary differential equations invariant manifold theorems have been a powerful tool for identifying the modes of the system which are most important for governing the long-time behavior of solutions as well as providing a way of computing the asymptotics of these solutions. On the other hand, if one studies the Navier-Stokes equations on $R^2$ or $R^3$ the phase space of the linearization of the equation does not seem to possess the "center", "stable", and "unstable" subspaces needed to apply the invariant manifold theory. However, rewriting the equations in terms of similarity variables we are able identify finite dimensional, invariant manifolds in the phase space which control the long-time behavior of solutions in a neighborhood of the origin and in the neighborhood of certain special vortex solutions, the Oseen or Burger's vortices. In two dimensions this leads to a very complete picture of the evolution of solutions -- any solution whose initial vorticity distribution is somewhat localized will converge, as time tends to infinity, to an explicit vortex solution at a computable (and optimal) rate. This is joint work with Prof. Thierry Gallay of the University of Grenoble.

**Gene Wayne**
*Boston University*

# Intermission

*2:30 PM-2:45 PM*

Thursday, May 29

# CP23

## Waves in the Visual Cortex

*2:45 PM-3:45 PM*

*Room: Ballroom I*

*Chair: Philip Ulinski, University of Chicago*

**2:45-3:00 Dynamical Systems Analysis of Propagating Waves in Turtle Visual Cortex**

Kay A. Robbins and David M. Senseman, University of Texas, San Antonio; *Philip Ulinski*, University of Chicago; and Bijoy K. Ghosh, Washington University, St. Louis

**3:05-3:20 Topographic Organization of Hebbian Neural Connections by Synchronous Wave Activity**

*Renate A. Wackerbauer*, University of Alaska, Fairbanks; and Eugene Mihaliuk and Kenneth Showalter, West Virginia University

**3:25-3:40 Extraction of Wave Structure from Biological Data**

David M. Senseman and *Kay A. Robbins*, University of Texas, San Antonio

Thursday, May 29

# CP24

## Topics in Pattern Formation - II

*2:45 PM-3:45 PM*

*Room: Magpie B*

*Chair: Cyrill B. Muratov, New Jersey Institute of Technology*

**2:45-3:00 A Kinetic Model of Oscillating Heterogeneous Catalytic Reaction with a Strange Attractor**

Lyubov Chumakova, University of Wisconsin, Madison; Natalia Chumakova, Boreskov Institute of Catalysis, Siberian Branch of Russian Academy of Sciences, Russia; and *Gennadii A. Chumakov*, Sobolev Institute of Mathematics, Siberian Branch of Russian Academy of Sciences, Russia

**3:05-3:20 An Asymptotic Stability Analysis of Static Spike Autosolitons in the One-Dimensional Gray-Scott Model**

*Cyrill B. Muratov*, New Jersey Institute of Technology; and Vyacheslav Osipov, Hewlett-Packard Research Laboratory

**3:25-3:40 Stochastic Modelling and Deterministic Limit of Catalytic Surface Processes**

Karl Oelschlaeger, Christian Reichert, and *Jens Starke*, University of Heidelberg, Germany; and Markus Eiswirth, Fritz-Haber Institut, Germany

Thursday, May 29

# CP25

## Waves in PDEs

*2:45 PM-3:45 PM*

*Room: Ballroom II*

*Chair: Eugene R. Tracy, College of William & Mary*

**2:45-3:00 Geometric Invariants of Multi-Dimensional Linear Wave Conversion**

*Eugene R. Tracy*, College of William & Mary; and Allan Kaumfman, LBNL and University of California, Berkeley

**3:05-3:20 An Integrable Hierarchy and Its Parametric Solution**

Zhijun Qiao, Los Alamos National Laboratory

**3:25-3:40 Qualitative Properties of Dynamical Problems for Nonlinear Electromagnetoelasticity System**

*Viatcheslav I. Priimenko*, North Fluminense State University, Brazil; and Mikhail P. Vishnevskii, Universidade Estadual de Norte Fluminense, Brazil

Thursday, May 29

# CP26

## Periodic Orbits and Homoclinic Orbits in Low-Dimensional Systems

*2:45 PM-3:25 PM*

*Room: Ballroom III*

*Chair: Elizabeth Bradley, University of Colorado, Boulder*

**2:45-3:00 Recurrence Plots and Unstable Periodic Orbits**

*Elizabeth Bradley*, University of Colorado, Boulder; and Ricardo Mantilla, University of Colorado

**3:05-3:20 Homoclinic Orbits in a Piecewise System and Its Relations with Invariant Sets**

Ibere L. Caldas and Murilo S. Baptista, University of Sao Paulo, Brazil; and *Rene O. Medrano-T.*, Universidade of São Paulo, Brazil

Thursday, May 29

# CP27

## Topics in Neuroscience - II

*2:45 PM-3:45 PM*

*Room: White Pine*

*Chair: Benjamin Lindner, University of Ottawa, Canada*

**2:45-3:00 Spatio-Temporal Dynamics in the Olfactory System**

Jens Starke and *Jürgen Reidl*, University of Heidelberg, Germany

**3:05-3:20 Simple Neural Architectures Generating Complex Syllables in Birdsong**

Gabriel B. Mindlin, University of Buenos Aires, Argentina

**3:25-3:40 Non-Renewal Spike Trains Generated by Stochastic Neuron Models**

Maurice J. Chacron, Andre Longtin, Jason Middleton, and *Benjamin Lindner*, University of Ottawa, Canada

Thursday, May 29

# CP28

## Passive Scalars, Chaotic Transport

*2:45 PM-3:45 PM*

*Room: Wasatch A*

*Chair: Sanjeeva Balasuriya, University of Sydney, Australia*

SESSION CANCELLED

**3:05-3:20 Advectio[illegible] in a Chaotic Ma[illegible]us**

Jean-[illegible]t, Imperial College, [illegible]gdom; and Stephen Childress, C[illegible]ant Institute of Mathematical Sciences, New York University

Thursday, May 29

# CP29

## Topics in Fluid Dynamics - II

*2:45 PM-3:45 PM*

*Room: Magpie A*

*Chair: Charles R. Doering, University of Michigan, Ann Arbor*

**2:45-3:00 Modeling the Slip of a Fluid at a Solid Interface at the Molecular Level**

Shreyas Mandre, Seth Lichter, and *Alexander C. Roxin*, Northwestern University

**3:05-3:20 Turbulent Energy Dissipation for Forced Flow in a Slippery Channel**

Bruno Eckhardt and Joerg Schumacher, Philipps-Universität, Marburg, Germany; and *Charles R. Doering*, University of Michigan, Ann Arbor

**3:25-3:40 Electrohydrodynamically Driven Chaotic Advection in a Bounded Stokes Flow**

George Homsy, Dmitri L. Vainchtein, and *Thomas Ward*, University of California, Santa Barbara

Thursday, May 29

# CP30

## Reaction-Diffusion Models of Biological and Chemical Species

*2:45 PM-3:25 PM*

*Room: Wasatch B*

**2:45-3:00 Modeling the Interaction of Key Players in Gradient Sensing in Dictyostelium**

Pablo A. Iglesias and *J. Krishnan*, Johns Hopkins University

**3:05-3:20 Long-Term Coexistence for a Competitive System of Spatially Varying Reaction-Diffusion Equations**

John Norbury and *Andrei Korobeinikov*, University of Oxford, United Kingdom; and Graeme Wake, University of Canterbury, New Zealand

Thursday, May 29

# CP31

## Bifurcations in Piecewise Smooth Systems

*2:45 PM-3:45 PM*

*Room: Maybird*

*Chair: Christopher K. Halse, University of Bristol, United Kingdom*

**2:45-3:00 Bifurcations in Grazing and Sliding Systems**

Mario Di Bernardo, Martin Homer, and *Christopher K. Halse*, University of Bristol, United Kingdom

**3:05-3:20 Effects of Noise on Border Collision Bifurcations**

John Hogan and *Tom Griffin*, University of Bristol, United Kingdom

**3:25-3:40 Bifurcations of a Two-Degree-of-Freedom System with Dry Friction**

A. Abadi, Utrecht University, The Netherlands

Thursday, May 29

# CP32

## Topics in Hamiltonian Dynamics

*2:45 PM-3:45 PM*

*Room: Superior A*

*Chair: Diego Del-Castillo-Negrete, Oak Ridge National Laboratory*

**2:45-3:00 From Eigenmodes of *N*-Body Hamiltonian Dynamics to Van Kampen-Case Distributions for Landau Damping and Instability**

Yves Elskens, CNRS-Universite de Provence, France

**3:05-3:20 High Dimensional Bowling**

Mikhail Deryabin, Moscow State University, Russia; and *Poul G. Hjorth*, Technical University of Denmark, Denmark

**3:25-3:40 Self-Consistent Chaos in a Mean Field Hamiltonian Model**

Diego Del-Castillo-Negrete, Oak Ridge National Laboratory

Thursday, May 29

# CP33

## Forced Hamiltonian Systems and Billiards

*2:45 PM-3:45 PM*

*Room: Superior B*

*Chair: Leonid V. Kuznetsov, University of North Carolina, Chapel Hill*

**2:45-3:00 Scaling of the Chaotic Layer**

Leonid V. Kuznetsov, University of North Carolina, Chapel Hill

**3:05-3:20 Microdisk Lasers, Billiards, and Subriemannian Geometry**

Vadim Zharnitsky, Lucent Technologies

**3:25-3:45 Parametric Excitation in Nonlinear Dynamics**

Taoufik Bakri, Utrecht University, The Netherlands

# Coffee Break

*3:45 PM-4:15 PM*

*Room: Golden Cliff*

Thursday, May 29

# MS57

## Vortex Based Estimation and Control

*4:15 PM-7:15 PM*

*Room: Magpie A*

In recent years, a class of reduced-order models that implement 3-D co-linear localized vortex filaments (2-D point vortices) has become a thriving topic of investigation. Applications of this model range from turbulence, to mixing, to geophysics. Its advantages, compared with solving the full Euler or Navier-Stokes equations, are particularly important when one must not just solve for the underlying dynamics, but also design practical control laws. This Minisymposium will address recent advances in this area with applications to concrete physical systems.

**Organizer: Paul K. Newton**

*University of Southern California*

**Organizer: Dmitri L. Vainchtein**

*University of California, Santa Barbara*

**4:15-4:40 Optimal Control of Vortex Pairs**

Igor Mezic and *Dmitri L. Vainchtein*, University of California, Santa Barbara

**4:45-5:10 Extended Kalman Filtering for Vortex Systems**

Kayo Ide, University of California, Los Angeles

**5:15-5:40 Assimilation of Tracer Data in Point Vortex Flows**

*Christopher Jones*, University of North Carolina; Leonid V. Kuznetsov, University of North Carolina, Chapel Hill; and Kayo Ide, University of California, Los Angeles

**5:45-6:10 The Infancy of Fluid Flow Control Using Point Vortex Models**

Luca Cortelezzi, McGill University, Canada

**6:15-6:40 Pattern Observers and Feedback With Point Vortex Models**

*Gilead Tadmor*, Northwestern University; Rudibert King, Technische Universität Berlin, Germany; and Bernd Noack, Mark Pastoor, and Andreas Dillmann, Technische Universitaet Berlin, Germany

**6:45-7:10 Capillary Collapse and Pinchoff of a Soap-Film Bridge**

*Monika Nitsche*, University of New Mexico; and Paul Steen, Cornell University

Thursday, May 29

# MS58

## Applications in Stochastic Nonlinear Dynamics

*4:15 PM-7:15 PM*

*Room: Magpie B*

Recent work has focused on understanding resonance-like complex oscillations which exist due to nonlinear interactions of random perturbation of an otherwise deterministic dynamical system. Deterministic systems which are nconsidered in the presence of noise, are being more prominently used to model real-world scenarios. Recently, progress has been made to understand the global role of noise in these systems. For example, we will discuss global transport mechanisms leading to noise-induced bursting activity in both laser and disease models. We will describe a spatial analogue of coherence resonance. We will also describe how understanding stochastic transport mechanisms naturally yields specialized control algorithms.

**Organizer: Erik Bollt**

*Clarkson University*

**Organizer: Lora Billings**

*Montclair State University*

**4:15-4:40 Stochastic Chaos Control-Theory and Applications**

Erik Bollt, Clarkson University; Lora Billings, Montclair State University; and *Ira B. Schwartz*, Naval Research Laboratory

**4:45-5:10 Noise Scaling of Statistical Averages in Chaotic Systems**

Zonghua Liu and *Ying-Cheng Lai*, Arizona State University

**5:15-5:40 Mapping Transport Activity in Stochastic Dynamics, Directly from The Transfer Operator**

*Erik Bollt*, Clarkson University; Lora Billings, Montclair State University; and Ira Schwartz, Naval Research Laboratory

**5:45-6:10 The Bifurcation to Stochastic Chaos in a 3D Laser Model**

Erik Bollt, Clarkson University; *Lora Billings*, Montclair State University; and Ira B. Schwartz and David S. Morgan, Naval Research Laboratory

**6:15-6:40 Enhancing Spatial Coherence by Noise: A Spatial Analogue of Coherence Resonance**
*Jordi Garcia Ojalvo*, Cornell University; and Oliver Carrillo and Jose Maria Sancho, Universitat de Barcelona, Spain

**6:45-7:10 Noise-Induced Exit of Periodically Driven Systems: Scaling Crossovers**
Dmitrii Ryvkine, Brage Golding, and *Mark I. Dykman*, Michigan State University

Thursday, May 29

# MS59 (For Part II, see MS 82)

## Asymptotic Analysis of Certain Geophysical and Hydrodynamic Flows

*4:15 PM-7:15 PM*

*Room: Ballroom I*

The minisymposium emphasizes recent progress in the asymptotic analysis of dissipative partial differential equations, especially those arising from fluid mechanical and geophysical models. The focus is mainly on: Long time behaviour of solutions, Asymptotic limits of partial differential equations in the presence of a small parameter, and boundary layer problems.

**Organizer: Mohammed B. Ziane**
*University of Southern California*

**Organizer: Igor Kukavica**
*University of Southern California*

**Organizer: Edriss S. Titi**
*University of California, Irvine and Weizman Institute of Science, Israel*

**4:15-4:40 Navier-Stokes-alpha Model and Boundary Layer Turbulence**
Alexey Cheskidov, Texas A&M University

**4:45-5:10 Kraichnan Turbulence via Finite Time Averages**
*Michael S. Jolly*, Indiana University; and Ciprian Foias, Indiana University and Texas A&M University

**5:15-5:40 Adjoint-based Iterative Methods for Robust Control in Fluid Mechanics: Application to Data Assimilation in Oceanography**
Theodore Tachim Medjo, Florida International University

**5:45-6:10 Emergence of Large Scale Structure Under Small Scale Random Forcing**
*Xiaoming Wang*, Iowa State University; and Andrew Majda, New York University

**6:15-6:40 Estimates for the Navier-Stokes Equations Pertaining to the Statistical Theory of 3D Stationary Turbulence**
Ricardo Rosa, Universidade Federal do Rio De Janeiro, Brazil

**6:45-7:10 Parametrisation of Attractors and Takens Embedding Theorem**
*James C. Robinson*, University of Warwick, United Kingdom; and Igor Kukavica, University of Southern California

Thursday, May 29

# MS60

## Canards: Theory and Applications

*4:15 PM-7:15 PM*

*Room: Wasatch A*

Canards are periodic orbits for which the trajectory in state space follows both the attracting and repelling parts of a slow manifold. They are associated with a dramatic change in the amplitude and period of a periodic orbit within a very narrow interval of a control parameter. First discovered for planar systems in the 1970's, canards and associated chaos have since been found for a variety of singularly perturbed systems. This minisymposium will cover recent results on the general theory of canards, and on applications to systems from physics, chemistry, and biology.

**Organizer: Jeff Moehlis**
*Princeton University*

**Organizer: Morten Brons**
*Technical University of Denmark, Denmark*

**4:15-4:40 Basics of Canards**
Morten Brons, Technical University of Denmark, Denmark

**4:45-5:10 Canards in a Surface Oxidation Reaction**
Jeff Moehlis, Princeton University

**5:15-5:40 Canards in Systems with 2-d Folded Critical Manifold**
Martin Wechselberger, Ohio State University

**5:45-6:10 Canards and Chaos in the Forced Van der Pol Equation**
John Guckenheimer, Cornell University; Kathleen A. Hoffman, University of Maryland, Baltimore County; and *Warren Weckesser*, Colgate University

**6:15-6:40 Canard Explosion and Canard Chaos**
Martin Krupa, New Mexico State University

**6:45-7:10 Canards in the Schroedinger Equation**
Peter Szmolyan, Vienna University of Technology, Austria

Thursday, May 29

# MS61

## Dimensional Reduction for Nonlinear Systems

*4:15 PM-7:15 PM*

*Room: Wasatch B*

The problem of reducing the number of dimensions necessary for prediction of behavior of nonlinear systems is a topic of much current interest. A number of different approaches have been proposed, including averaging (coarse graining), proper orthogonal decomposition and optimal prediction. At this minisymposium we will discuss these various approaches. Averaging of Navier-Stokes and Euler equations to obtain coarse-grained equations at large scale is a problem of great fundamental and practical importance. A new approach to the theory of Lagrangian averaging will be presented in a talk by Marsden. The same problem of coarse graining, for different classes of equations will be considered analytically and numerically by Dellnitz and Kevrekidis. The theory of optimal prediction in the context of mechanical models of heat baths will be presented by Kupferman. Application of the Proper Orthogonal Decomposition technique to simulation of large-scale interconnected systems will be discussed by Petzold, while connection between model reduction of a nonlinear system and the spectral properties of the associated Koopman operator will be described by Mezic.

The minisymposium will provide the speakers and the audience with a chance to compare and discuss the various approaches to model reduction and propose possible synergies between them.

**Organizer: Igor Mezic**
*University of California, Santa Barbara*

**Organizer: Raz Kupferman**
*Hebrew University, Israel*

**4:15-4:40 Dimensional Reduction and Spectral Properties of the Koopman Operator**
Igor Mezic, University of California, Santa Barbara

**4:45-5:10 Model Reduction in Mechanical Models of Heat Baths**
Raz Kupferman, Hebrew University, Israel

**5:15-5:40 On the Identification of Macroscopic Dynamics**
Michael Dellnitz, University of Paderborn, Germany

**5:45-6:10 Reduction and Reconstruction for Self-similar Dynamical Systems**
*Jerrold E. Marsden*, California Institute of Technology; Kurt Lust, K.U.Leuven, Belgium; and Clancy W. Rowley and Ioannis Kevrekidis, Princeton University

**6:15-6:40 Coarse Control and Coarse Optimal Paths for Microscopic/ Stochastic Simulators**
Antonios Armaou, Pennsylvania State University; and Constantinos Siettos and *Yannis Kevrekidis*, Princeton University

**6:45-7:10 Model Reduction, Coarse Graining, and the Renormalization Group**
David Reynolds, University of California, Santa Barbara

Thursday, May 29

# MS62 (For Part I, see MS38)

## Discrete Geometry and Geometric Integration

*4:15 PM-7:15 PM*

*Room: Ballroom III*

Continuous systems may have various geometric and invariant properties, such as energy and momentum conservation, as well as symplecticity, and it is desirable for numerical simulations to preserve these invariants whenever possible.

Geometric integration is concerned with the development and analysis of such structure-preserving discretizations, and further advances in the field are facilitated by a thorough understanding of the geometry of the discretized system.

This minisymposium will review some recent advances in geometric integration as well as efforts to understand geometry at an intrinsically discrete level. It will also serve to enhance the interaction between these two mutually complementary fields.

**Organizer: Claudia Wulff**
*University of Surrey, United Kingdom*

**Organizer: Jerrold E. Marsden**
*California Institute of Technology*

**Organizer: Melvin Leok**
*California Institute of Technology*

**4:15-4:40 Geometric Integrators for Non-smooth Collisions**
Matthew West, University of California, Davis

**4:45-5:10 A Discrete-Time Formulation of Hamiltonian Mechanics**
Matthew West, University of California, Davis; and *Sanjay Lall*, Stanford University

**5:15-5:40 On the Algebraic Structure of Lie-Butcher Series**
Hans Munthe-Kaas, University of Bergen, Norway

**5:45-6:10 Multidimensional Consistency of Discrete Equations as the Fundamental Integrability Principle**
Yuri Suris, Technische Universität Berlin, Germany

*MS 62, continued*

**6:15-6:40 Geometric Particle-mesh Methods for Geophysical Fluid Dynamics**

*Jason Frank*, Centrum voor Wiskunde en Informatica, The Netherlands; and Sebastian Reich, Imperial College of London, United Kingdom

**6:45-7:10 Bridging Time Scales in Structural Mechanics: Asynchronous Variational Integrators**

Adrian Lew, California Institute of Technology

Thursday, May 29

## MS63 (For Part II, see MS73)

## Mechanical Models of DNA

*4:15 PM-7:15 PM*

*Room: Ballroom II*

Mechanical deformation of DNA imposed by proteins or other ligands plays an important role in intracellular biological processes. The need for understanding DNA mechanics has stimulated the development of several approaches ranging from classical elastic rod theories to discrete mesoscopic statistical models. In this minisymposium, we will focus on recent advances in modeling DNA deformability and investigations of its biological implications.

**Organizer: David Swigon**

*Rutgers University*

**Organizer: Robert S. Manning**

*Haverford College*

**4:15-4:40 Theory of Sequence-Dependent DNA Elasticity**

David Swigon, Wilma K. Olson, and *Bernard D. Coleman*, Rutgers University

**4:45-5:10 Insights into DNA Folding from Elastic Rod Theory**

*Tom Bishop*, School of Public Health & Trop. Medicine; and Oleksandr Zhmudsky, Tulane University

**5:15-5:40 Sensitivity of DNA Minicircle Energies to Several Shape and Flexibility Parameters**

Robert S. Manning, Haverford College

**5:45-6:10 Control of Transcription by DNA Looping**

Bernard D. Coleman, Wilma K. Olson, and *David Swigon*, Rutgers University

**6:15-6:40 DNA Minicircles: Comparison of Mechanical and Statistical Mechanical Analysis**

Alexander Vologodskii, New York University

**6:45-7:10 Experimental and Computational Studies of DNA Minicircles**

Alexandre Vetcher, Hua Tsen, and *Stephen Levene*, University of Texas, Dallas

Thursday, May 29

# MS64

## Methods of Dimension Reduction in Models of Neural Systems

*4:15 PM-7:15 PM*

*Room: Superior A*

In larger neural models described by systems of differential equations, the total phase space dimension is typically too high to apply standard low-dimensional techniques from dynamical systems theory.

However, neural systems exhibit many distinguishable scales, strong internal dependencies, and symmetries. These can be intrinsic, or due to interesting behavioural states, like phase-locking or travelling wave solutions. Despite intuition for the effective low dimensionality of the dynamics, we seek appropriate methods for determining the origin of the low-dimensional structure from the original equations, and its bifurcation properties.

We present examples of reductions using spike time maps, multiple scale analysis, and invariant manifold theory.

**Organizer: Robert Clewley**
*Boston University*

**Organizer: G Bard Ermentrout**
*University of Pittsburgh*

**4:15-4:40 Multiple Scale Analysis and Local Models Generate Low-dimensional Maps**
Nancy Kopell and *Robert Clewley*, Boston University

**4:45-5:10 The Virtues of Being Slow**
G Bard Ermentrout, University of Pittsburgh

**5:15-5:40 Scale-up for Cortical Modelling**
David W. McLaughlin, Courant Institute of Mathematical Sciences, New York University

**5:45-6:10 The Existence and Stability of Phase-locked States in Coupled Phase Response Curves**
G Bard Ermentrout and *Pranay Goel*, University of Pittsburgh

**6:15-6:40 Mapping Dynamics of Coupled Nonlinear Neural Oscillators: Effects of Strong Coupling**
Nancy Kopell, John A. White, and *Corey D. Acker*, Boston University

**6:45-7:10 Epilepsy in Small-World Networks**
John A. White, Robert Clewley, Scott Arno, Tara Keck and *Theoden Netoff*, Boston University

Thursday, May 29

# MS65

## Models of Dynamics, and Dynamics of Models

*4:15 PM-7:15 PM*

*Room: Superior B*

Dynamics is, at it's heart, an experimental discipline. From the rapid motion of turbulent mixing to the slow motion of plant growth, dynamics abound on all scales, and careful measurements combined with accurate mathematical modeling ultimately leads to improved understanding of the complex systems in which we live. We propose a minisymposium in which experiments would figure prominently. Zhang will present some experiments on flexible structures in fluid flows. McLaughlin will present some experiments on spheres propagating in a stratified fluid. Alain Goriely will present some experiments on tendril propagation in climbing vines. Mark Levi will present some results on nonholnomic constraints and rapidly varying systems. All of these talks involve a combination of theory and experiment. At least one experiment (Levi) will be presented live.

**Organizer: Jared Bronski**
*University of Illinois, Urbana-Champaign*

**Organizer: Richard McLaughlin**
*University of North Carolina, Chapel Hill*

**4:15-4:40 An Internal Splash: Falling Spheres in Stratified Fluids**
David Adalsteinsson, Nicole Abaid, and *Richard McLaughlin*, University of North Carolina, Chapel Hill; and Akua Aguapong, Hampton University

**4:45-5:10 Stability Webs in Hill's Equations**
Mark Levi, Pennsylvania State University

**5:15-5:40 Experiments from your Backyard: Tendril Perversion and Twining Vines**
Alain Goriely, University of Arizona

**5:45-6:10 Playful Boundary in Moving Fluids: Experimental Studies on Flexible Structures in Fluid Flows**
Jun Zhang, Courant Institute of Mathematical Sciences, New York University

**6:15-6:40 Polymorphic Flagella and Coiling Fluid Jets: Helical Dynamics in Biology and Physics**
Raymond Goldstein, University of Arizona

**6:45-7:10 Turbulent Entrainment in the Upper Layer of an Ocean Fish-tank**
Roberto Camassa, University of North Carolina, Chapel Hill

Thursday, May 29

# MS66 (For Part I, see MS 42)

## Pattern Formation through Nonlocal Interactions

*4:15 PM-6:45 PM*

*Room: Maybird*

In many physical systems, nonlocal interactions play a crucial role in pattern formation. Such nonlocal interactions can range from long-range connections between elements of a system, to competition for resources among elements, to the presence of global signaling agents. These show up in a wide variety of applications, from vision and other neuroscience arenas, to materials science, to propagation of activity in biological or chemical excitable media. The goal of this minisymposium is to survey both the types of mathematical techniques being used to handle nonlocal problems and the range of physical situations in which they arise.

**Organizer: Jonathan E. Rubin**
*University of Pittsburgh*

**Organizer: William Troy**
*University of Pittsburgh*

**4:15-4:40 Spatial Symmetry Breaking with Light-Induced Remote Communication**
Henrik Skødt, University of Copenhagen, Denmark; and *Kenneth Showalter*, West Virginia University

**4:45-5:10 Stabilization of Bumps by Noise**
Carlo R. Laing, Massey University, New Zealand

**5:15-5:40 Localized Pattern Formation Without Recurrent Excitation**
William Troy and *Jonathan E. Rubin*, University of Pittsburgh

**5:45-6:10 The Evans Function for Equations with Nonlocal Terms**
Bjorn Sandstede, Ohio State University

**6:15-6:40 Traveling Waves for a Bistable Equation with Nonlocal and Indefinite Interaction**
Peter Bates, Michigan State University

Thursday, May 29

# MS67

## Stabilization of Wave Solutions to Singularly Perturbed Partial Differential Equations

*4:15 PM-7:15 PM*

*Room: White Pine*

Recent investigations into non-linear systems supporting wave solutions have revealed interesting novel stability phenomena. Such phenomena are often counter-intuitive. Examples of stabilizing mechanisms and bifurcations have been found in systems such as the Gray-Scott (GS) and Gierer-Meinhardt (GM) models. These mechanisms usually involve non-local effects or are related to multiple (time) scales. Many of the ideas and methods to analyze the effects have been developed in the context of the GS and GM models. This mini-symposium will focus on a broader context. Examples include Josephson junctions and the Ginzburg-Landau equations.

**Organizer: David Iron**
*University of Amsterdam, Netherlands*

**Organizer: Geertje M. Hek**
*University of Amsterdam, Netherlands*

**4:15-4:40 Stabilization by Diffusion in a Coupled Ginzburg-Landau Equation**
Arjen Doelman, Nienke Valkhoff, and *Geertje M. Hek*, University of Amsterdam, Netherlands

**4:45-5:10 The Eigenvalue Problem for Perturbed Integrable Systems**
Bjorn Sandstede, Ohio State University; and *Todd Kapitula*, University of New Mexico

**5:15-5:40 On a Stable Double Heteroclinic Loop Pulse of Saddle-Focus Type**
Yasumasa Nishiura, Hokkaido University, Japan

**5:45-6:10 Destabilization of Fronts in a Class of Bi-Stable Systems**
David Iron, University of Amsterdam, Netherlands

**6:15-6:40 Travelling Waves in a Singularly Perturbed Sine-Gordon Equation**
Gianne Derks, University of Surrey, United Kingdom; Arjen Doelman, University of Amsterdam, Netherlands; and Timco Visser and *Stephan A. Van Gils*, University of Twente, Netherlands

Thursday, May 29

# Dinner Break

*7:15 PM-8:30 PM*

*Attendees on Their Own*

# Poster Session

*8:30 PM-10:00 PM*

*Room: Ballroom and Foyer*

**Distinct Synaptic Pathways Control the Frequency of a Rhythmic Network**
*Christina Ambrosio*, New Jersey Institute of Technology; Farzan Nadim, NJIT & Rutgers University; Yair Manor, Ben-Gurion University of the Negev and Zlotowski Center, Isreal; Amitabha K. Bose, New Jersey Institute of Technology

**Renormalization and Destruction of Tori in the Standard Nontwist Map: Recent Results**
*Amit Apte*, Alexander Wurm, and P.J. Morrison, University of Texas, Austin

**Determination of Interaction Mechanism from Time Series**
*Boris Bezruchko*, Vladimir Ponomarenko, and Dmitry Smirnov, Institute of Radio-Engineering and Electronics, Russian Academy of Sciences, Russia

**Chaos and Self-Oscillatory Regimes in Ecological Systems**
*Tolibjon E. Buriev* and Vafokul Ergashevlast Name, Samarkand State University, Uzbekistan

**A Canonical Model of Cascades of Mediating Signaling Molecules in Metabolic Cellular Circuits**
John M. Burke, Arizona State University

**Separation of Bioparticles with Multiple-Frequency Traveling Wave Dielectrophoresis**
*Dong Eui Chang,* University of California, Santa Barbara; Sophie Loire, Universite de Bordeaux I, France; Igor Mezic, University of California, Santa Barbara

**Evaluating Causal Relations Among Multiple Nonlinear Time Series**
*Yonghong Chen,* Xi'an Jiaotong University, P.R. China; Govindan Rangarajan, Indian Institute of Science, Bangalore, India ; Mingzhou Ding, Florida Atlantic University

**Channeling Behavior in a Polymer Gel Model**
*Nick G. Cogan*, Tulane University; James P. Keener, University of Utah

**Theory of the Dependence of Dna Configurations on Salt Concentration**
*Bernard D. Coleman* and David Swigon, Rutgers University; Yoav Biton, Rutgers University

**Pattern Formation in a Network of Excitatory and Inhibitory Cells with Adaptation**
*Rodica Curtu* and G Bard Ermentrout, University of Pittsburgh

**Front Dynamics in Reaction-Diffusion Systems with Fractional Diffusion**
*Diego Del-Castillo-Negrete*, Benjamin Carreras, and Vickie Lynch, Oak Ridge National Laboratory

**A Fractal Model of the Big Bang**
Jorge Diaz, University of the Sacred Heart, Puerto Rico

**Neural Oscillations in the Brain: Methods of Analysis and Functions**
Mingzhou Ding, Florida Atlantic University

**Fast, High-Quality, Numerical Shadowing**
Mitrajit Dutta, University of New Hampshire

**Analytical Search for Bifurcation Surfaces in Parameter Space**
*Thilo Gross*, Carl von Ossietzky Universitaet Oldenburg; Ulrike Feudel, University of Oldenburg, Germany

**Existence and Stability of Localized Pulses in Neural Networks**
*Yixin Guo* and Carson C. Chow, University of Pittsburgh

**Cross-over Behaviour in a Communication Network**
*Neelima Gupte* and Brajendra Singh, Indian Institute of Tecnology Madras, India

**Transport Rates for Asteroids and Molecules**
*Mirko Hessel*, Michael Dellnitz, and Oliver Junge, University of Paderborn, Germany

**Chaotic Scattering on 1-D Dynamics and Chaotic Scattering Under Attraction Basin Crises**
Heyder Hey, Brazilian National Institute for Space Research - INPE, Brazil

**Construction of the Simplest Model to Explain Complex Receptor Activation Kinetics**
*Poul G. Hjorth* and Peter Roegen, Technical University of Denmark, Denmark; Robert Bywater, Novo Nordisk; Allan Sorensen, Maersk Institute for Production Technology, Denmark

**Phase Locking in an Integrate-and-fire Neuron Model with Interspike Interval Threshold Modulation and Refractory Periods**
*Matt D. Holzer*, Montana State University; Tomas Gedeon, Montana State University

**Localised Solutions in Magnetoconvection**
Steve Houghton, University of Cambridge, United Kingdom

**Discrete Time Model of Bark Beetle Infestations and Epidemic Waves**
*Giao Huynh* and Kelly J. Black, University of New Hampshire; James Powell, Utah State University; Bentz Barbara and Jesse Logan, USDA Forest Service

**Vanishing Twist in the Hopf Bifurcation**
*Alexei Ivanov*, Loughborough University, United Kingdom; Holger R. Dullin, Loughborough University, United Kingdom

**Coupled Map Lattice Models of Tree Migration**
*Miaohua Jiang* and Adam Dickey, Wake Forest University

**Complete Replacement of Chaotic Uncertainty with Transmitted Information**
*Matthew Kennel*, University of California, San Diego; Shawn Pethel, US Army AMCOM

**Equilibria by Superposition**
Bharat Khushalani, University of Southern California

**Oscillatory Marangoni Convection in Binary Mixtures in Square and Nearly Square Containers**
*Edgar Knobloch*, University of Leeds, United Kingdom; Alain Bergeon, IMFT, France

**Modeling of Dynamics of the Plasmodium of True Slime Mold**
*Ryo Kobayashi* and Toshiyuki Nakagaki, Hokkaido University, Japan

**Dynamics of Multiple Sclerosis**
*Yoshi-Hisa Kubota*, Stanford University School of Medicine

**Control of Integrable Hamiltonian Systems**
*Christopher W. Kulp* and Eugene Tracy, College of William & Mary

**A Two-Variable Model of Somatic-Dendritic Interactions in a Bursting Neuron**
Carlo R. Laing, Massey University, New Zealand

**A Discrete Theory of Connections on Principal Bundles**
Melvin Leok, California Institute of Technology

**Global Attractivity of Nash Equilibria of a Labor-Managed Oligopoly**
*Weiye Li*, Los Alamos National Laboratory; Marek Rychlik, University of Arizona

**Symbolic Dynamics for Homoclinic Tangles with Asymmetric Perturbations**
*Anna Litvak-Hinenzon*, University of Warwick, United Kingdom

**Propagation and Immunization of Infection on General Networks with Both Homogenous and Heterogeneous Components**
*Zonghua Liu*, Ying-Cheng Lai, and Nong Ye, Arizona State University

**Time-Periodic Solutions of the Complex Ginzburg-Landau Equation**
*Vanessa Lopez*, University of Illinois, Urbana-Champaign; Philip Boyland, University of Florida; Michael Heath, University of Illinois, Urbana-Champaign; Robert Moser, University of Illinois

**Time-Optimal Control of the Dynamic System of a 2-D Rigid Cylinder and a Point Vortex**
Zhanhua Ma, New Mexico State University

**Synchronization in Nonhyperbolic Hyperchaotic Systems**
*Elbert E. Macau*, LIT - Laboratory of Integration and Testing INPE - Brazilian Institute for Space Research, Brazil; Celso Grebogi, Universidade de Sao Paulo/USP, Brazil; Ying-Cheng Lai, Arizona State University

**Associative Memory Based on a Symmetric-Global Coupled Map Architecture with Feedback**
*Elbert E. Macau*, LIT - Laboratory of Integration and Testing INPE - Brazilian Institute for Space Research, Brazil; Juliano Sansao, Embraer

**Normal Forms for Non-Linear Systems of High Codimension with Nilpotent Linear Part**
David Malonza, Iowa State University

**Existence and Stability of N-Pulses in Optical Fibers with Periodic Phase-Sensitive Amplifiers.**
Vahagn E. Manukian, Ohio State University

**Dynamic Modeling of Free-Running Hamster Circadian Rhythms**
*Matthew R. Marler*, University of California, San Diego; Jeffery Elliott, University of California, San Diego

**Weakly-Nonlinear Behavior of Non-Newtonian Instabilities in Core-Annular Flow**
*Joel Miller* and Michael Proctor, University of Cambridge, United Kingdom

**Model-Based Experimental Design for Quantification of Geochemical and Microbial Immobilization of Uranium and Arsenic in Groundwater Systems**
Diana Burghardt, Andrea Kassahun, and *Mike Mueller*, Dresden Groundwater Research Center, Germany

**Cellular Computation by Adaptive Changes in Body Shape of An Amoeba-Like Organism**
*Toshiyuki Nakagaki* and Ryo Kobayashi, Hokkaido University, Japan

**Presentaion of The 5 Cardiac Sites Web For Modelling and Simuling the Model Pacemaker and the Cardiac Simulator**
*Dit Papa Lamine L. Ndao*, S/C Ecole Superieure Polytechnique, Dakar Senegal

**Phase Oscillator Neural Networks with Error-Free Memory Recall**
*Takashi Nishikawa*, Frank C. Hoppensteadt, and Ying-Cheng Lai, Arizona State University

**Reduction of Interacting-Front Dynamics in Nonlinear Delayed-Feedback Systems**
*Michel Nizette*, Université Libre de Bruxelles, Belgium

**Explicit Formulae for Stability of Oscillations**
*Michal Odyniec* and Lyndie Williamson, Signature BioScience Inc.

**Invariant Manifolds and Space Mission Design**
*Kathrin Padberg*, Michael Dellnitz, and Oliver Junge, University of Paderborn, Germany

**Analysis of Super Subdivision of Vonkoch Snow Flake**
Thirumurugan Shanmugam, Anna University, India; Thehazhnan P, A.C.Tech, Anna Univeristy, India; *Vivekanandan Periyasamy*, Anna University, India

**A Contact Problem from the Theory of Buckling Rods**
*Bob Planqué*, CWI, Netherlands; L. A. Peletier, Leiden University, Netherlands; G.H.M. van der Heijden, University College London, United Kingdom

**A Geometric Analysis of the Lagerstrom Model: Existence of Solutions and Rigorous Asymptotic Expansions**
Nikola Popovic, Vienna University of Technology, Austria

**Heteroclinic Networks in Rotating Convection**
Claire Postlethwaite, University of Cambridge, United Kingdom

**Stability Analysis of Coupled Neural Systems**
Govindan Rangarajan, Indian Institute of Science, Bangalore, India

**A Measure of Oscillation Frequency for Time-Series, Robust to Arbitrary Linear Filtering**
Axel Rossberg, University of Freiburg, Germany

**Nontrivial Mappings in the Generalized Synchrony of Chaos**
*Nikolai Rulkov*, University of California, San Diego; Valentin Afraimovich and Albert Cordonet, IICO-UASLP, Mexico

**Convergence of the Gap-Tooth Scheme for Microscopic Simulations in Large Domains**
*Giovanni Samaey* and Dirk Roose, Katholieke Universiteit Leuven, Belgium; Kurt Lust, K.U.Leuven, Belgium

**Opening a Closed Hamiltonian Map**
*Miguel A. Sanjuan*, Universidad Rey Juan Carlos, Spain; Takehiko Horita, University of Tokyo, Japan; Kazuyuki Aihara, University of Tokyo, Japan

**Application of Nonlinear Time Series Methods to Modeling of a Complex Biological System**
*Dmitry Smirnov* and Boris Bezruchko, Institute of Radio-Engineering and Electronics, Russian Academy of Sciences, Russia; Ilya Sysoev, Saratov State University, Russia

**Noisy Pattern Precursors in An Optical System**
*Christophe Szwaj* and Gonzague Agez, PHLAM - Universite de Lille, France; Pierre Glorieux and Eric Louvergneaux, Universite de Lille 1, France

**Complex Behavior in a Plasma Device**
*Maisa O. Terra*, ITA - Technological Institute of Aeronautics; J.J. Barroso, Brazilian National Institute for Space Research - INPE, Brazil

**Spike-Time Attractors in Cortical Neurons**
Paul Tiesinga, University of North Carolina; *Peter J. Thomas*, Jean-Marc Fellous, and Terrence Sejnowski, Salk Institute for Biological Studies

**A Modified Lorenz Model**
*Rosa M. Velasco*, Universidad Autonoma Metropolitana (Iztapalapa), Mexico; Arturo Pérez-Xochitiotzin and Mirna Cuautle-Aguilar, Instituto Tecnológico Superior de Atlixco

**Chaos, Nonintegrability and Diffusion in Some Hamiltonian Systems with Saddle-Centers**
Kazuyuki Yagasaki, Gifu University, Japan

**Integrated Modelling of Aquatic Ecosystem and Contaminants**
*Jose M. Zaldivar* and Martin Plus, European Commission Joint Research Center, Italy

# Friday, May 30

## Registration
*8:00 AM-4:30 PM*
*Room: Ballroom Lobby*

## Game Room
*8:00 AM-12:00 AM*
*Room: Eagles Nest*

## MS68 (For Part II, see MS 90)
### Computing Manifolds: Techniques and Challenges
*8:30 AM-10:30 AM*
*Room: Ballroom I*

The invariant and implicitly defined manifolds often play a key role in the analysis of the underlying mathematical model. For example, in a given dynamical system, the stable and unstable manifolds of certain invariant sets essentially serve as a skeleton of the global dynamics of that system. On the other hand, implicitly defined manifolds appear when analyzing bifurcation phenomena.

The aim of this mini-symposium is to give an overview of the state of the art in methods for computing the manifolds. The speakers will mainly focus on the algorithmic aspects of the various approaches and emphasize both advantages and drawbacks of the respective methods.

**Organizer: Oliver Junge**
*University of Paderborn, Germany*

**Organizer: Alexander Vladimirsky**
*Cornell University*

**8:30-8:55 A Set Oriented Approach to the Computation of Invariant Manifolds**
Oliver Junge, University of Paderborn, Germany

**9:00-9:25 On the Computation Nonsmooth Center Manifolds**
*Michael S. Jolly*, Indiana University; and Ricardo Rosa, Universidade Federal do Rio De Janeiro, Brazil

**9:30-9:55 Manifolds in the Lorenz System**
Bernd Krauskopf and *Hinke M. Osinga*, University of Bristol, United Kingdom

**10:00-10:25 Ordered Upwind Methods for the Invariant Manifolds**
John Guckenheimer and *Alexander Vladimirsky*, Cornell University

Friday, May 30

## MS69 (For Part II, see MS 92)
### Dynamics of Complex Networks
*8:30 AM-10:30 AM*
*Room: Magpie A*

Complex networks of dynamical elements often appear as natural models for a variety of real-world systems, such as social networks, neural networks, and the Internet. The rapid development over the recent years has shown that many examples of networked systems share common topological characteristics, such as small-world and scale-free properties, and that the dynamics of the network is strongly affected by them. The speakers of this minisymposium will explore this interplay between the topology and the dynamics of complex networks in several different contexts, including growing networks, epidemic processes, attack vulnerability, election dynamics, and synchronization.

**Organizer: Takashi Nishikawa**
*Arizona State University*

**Organizer: Adilson E. Motter**
*Arizona State University*

**8:30-8:55 Epidemic Processes on Networks**
Mark Newman, University of Michigan/ Santa Fe Institute

**9:00-9:25 A Unified Prediction of Computer Virus Spread in Connected Networks**
William Spears, University of Wyoming; *Lora Billings*, Montclair State University; and Ira B. Schwartz, Naval Research Laboratory

**9:30-9:55 Evolving Networks with Multispecies Nodes and Spread in the Number of Initial Links**
Edward Ott and *Brian R. Hunt,* University of Maryland, College Park; and Jong-Won Kim, Max Planck Institute for Complex Systems, Germany

**10:00-10:25 Heterogeneity in Oscillator Networks: Are Smaller Worlds Easier to Synchronize?**
Adilson E. Motter, Ying-Cheng Lai, Frank C. Hoppensteadt, and *Takashi Nishikawa*, Arizona State University

Friday, May 30

## MS70 (For Part II, see MS 94)
### Frontiers in Chemotaxis Modeling
*8:30 AM-10:30 AM*
*Room: Ballroom III*

Chemotaxis, or more general chemosensitive movement, describes the active orientation of individuals or populations along chemical signal. A detailed investigation of the pattern forming properties of chemotaxis is necessary to understand aggregations in slime molds, localization and polarization in an embryo, trace following of leukocytes, mechanisms for angiogenesis and tumor development, etc. Models for chemotaxis are generally framed as continuous models in the form of partial (integro-) differential equations, or as individual-based computer models, such as cellular automata or stochastic models. Recently many results on both types of models have been obtained and many mechanisms are understood quite well. This makes a minisymposium on this topic very timely.

The purpose of this Minisymposium is, first to present the current state of the art in chemotaxis modeling, secondly to compare different model types, and finally to identify evident and important new questions and to discuss new approaches and new ideas. Purpose: The theory of Dynamical Systems is the major tool in the study of chemotaxis models. On the other hand, the variety of patterns in chemotaxis models has initiated great interest from the theoretical point of view. For example the study of finite time blow-up, or of ultra long transients, has stimulated new ideas in Dynamical System theory.

**Organizer: Hans G. Othmer**
*University of Minnesota, Minneapolis*

**Organizer: Thomas J. Hillen**
*University of Alberta, Canada*

**8:30-8:55 Stochastic Dynamics of Chemotaxis: Beyond the Keller-Segel Equations**
Timothy J. Newman, Arizona State University

**9:00-9:25 Modelling Micro to Macro in Chemotaxis and its Role in Development**
Kevin Painter, Herriott-Watt University, Edinburgh, Scotland

**9:30-9:55 On the Relation Between Kinetic Transport Models and Fluid Models for Chemotaxis**
Christian Schmeiser, University of Vienna, Austria

*MS 70 continued*

**10:00-10:25 From Signal Detection to Behavioral Response: An Integrated Model for Bacterial Chemotaxis**
Hans G. Othmer, University of Minnesota, Minneapolis

Friday, May 30
# MS71
## Gel Dynamics
*8:30 AM-10:30 AM*
*Room: Magpie B*

Mankind has only recently begun to utilize the unique material properties of gels; whereas, nature has long exploited them. Gels maintain structural integrity in blood clots and biofilm clusters, mediate diffusion in drug delivery systems and generate force moving Myxobacteria. In these examples, the structure and dynamics of the gel plays a fundamental role in the behavior of the system. This minisymposium will address models of gel dynamics with the goal of describing the mathematical treatment of fundamental gel dynamics in the context of biological applications such as blood clotting, biofilm systems, drug delivery and cellular motility.

**Organizer: N. G. Cogan**
*University of Utah*

**Organizer: C W. Wolgemuth**
*University of Connecticut Health Center*

**8:30-8:55 The Hydration Dynamics of Polyelectrolyte Gels With Applications to Cell Motility**
C W. Wolgemuth, University of Connecticut Health Center

**9:00-9:25 Enzymatic Degradation of Insoluble Fibrillar Gels**
Rami Tzafriri, Harvard-MIT Biomedical Engineering Center

**9:30-9:55 A Continuum Approach to Modeling Platelet Aggregation**
Aaron L. Fogelson and *Robert Guy*, University of Utah

**10:00-10:25 Mechanisms for Biofilm Heterogeneity**
*Nick G. Cogan*, Tulane University; and James P. Keener, University of Utah

Friday, May 30
# MS72 (For Part II, see MS 95)
## Localized and Synchronized Patterns via Local and Non-local Interactions
*8:30 AM-10:30 AM*
*Room: Wasatch A*

The minisymposium brings together modeling, analytical, computational and experimental studies in which different types of interactions are found to influence pattern dynamics. Key dynamical features, such as singular perturbations, canards, memory and delay, also contribute to localization, clustering, and synchronization. The talks compare and contrast different mechanisms which lead to various non-trivial behaviors. Part I focuses on spikes in reaction-diffusion systems, bump-type solutions in integro-differential equations, and firing patterns in coupled neurons. Part II concentrates on global coupling, with and without delay, and mechanisms leading to clustering and localization in models and experiments of chemical reactions.

**Organizer: Horacio Rotstein**
*Boston University*

**Organizer: Rachel Kuske**
*University of British Columbia, Canada*

**8:30-8:55 Stable Two Bump Solutions of Memory Models**
Carlo R. Laing, Massey University, New Zealand; and *William Troy*, University of Pittsburgh

**9:00-9:25 Semi-Srong Pulse Interactions**
*Arjen Doelman*, University of Amsterdam, Netherlands; and Tasso J. Kaper, Boston University

**9:30-9:55 Spike Dynamics of a Reaction-Diffusion Equation and a Conjecture About the Modified Green's Function**
Michael Ward and *Theodore Kolokolnikov*, University of British Columbia, Canada

**10:00-10:25 Transients, Mixed-Mode Oscillations, and Canards in a Coupled Oscillator Model of the Dopaminergic Neuron**
Georgi Medvedev, Drexel University

Friday, May 30

## MS73 (For Part I, see MS 63)

### Mechanical Models of DNA - Part II

*8:30 AM-10:30 AM*

*Room: Ballroom II*

Mechanical deformation of DNA imposed by proteins or other ligands plays an important role in intracellular biological processes. The need for understanding DNA mechanics has stimulated the development of several approaches ranging from classical elastic rod theories to discrete mesoscopic statistical models. In this minisymposium, we will focus on recent advances in modeling DNA deformability and investigations of its biological implications.

**Organizer: David Swigon**
*Rutgers University*

**Organizer: Robert S. Manning**
*Haverford College*

**8:30-8:55 Conformational Mechanics of DNA Phase Transitions**
Wilma K. Olson, Rutgers University

**9:00-9:25 DNA Structural Transitions and their Roles in Mechanisms of Regulation**
Craig J. Benham, University of California, Davis

**9:30-9:55 Base-pair and Continuum Mechanics Models of DNA**
Oscar Gonzalez, University of Texas

**10:00-10:25 What Does the NDB Say About DNA Structure? A Statistical Survey of the NDB Database**
*Armando D. Solis*, Mount Sinai School of Medicine; and Craig J. Benham, University of California, Davis

Friday, May 30

## MS74 (For Part II, see MS 96)

### Neural Dynamics and Behavior

*8:30 AM-10:30 AM*

*Room: Wasatch B*

A fundamental challenge in systems neuroscience is to understand how activity in neural circuits gives rise to behavior in animals. Recent advances in experimental recording techniques and data analysis have allowed neuroscientists to correlate specific neuronal network activity with specific behaviors. However, in most circumstances, the biophysical mechanisms underlying the neuronal activity remain unclear. Mathematical modeling is helping to uncover these mechanisms, and it could provide further insight into the behavior of the animal.

In this minisymposium, speakers will discuss biophysical mathematical models of various neural systems (sensorimotor, motor, communication, and sound localization), emphasizing the link between behavior and the underlying physiology.

**Organizer: Alla Borisyuk**
*Ohio State University*

**Organizer: Timothy J. Lewis**
*New York Univ/Center for Neural Sci and Courant Inst.*

**8:30-8:55 Interactions Between Distinct Motor Behaviors Determined by Feedback to Modulatory Neurons**
Farzan Nadim, NJIT & Rutgers University

**9:00-9:25 Inhibitory Delayed Feedback Required for Differential Responses to Prey and Communication Stimuli**
Brent D. Doiron, University of Ottawa, Canada

**9:30-9:55 Modeling Neural Mechanisms of Selectivity and Sequence Generation in the Songbird**
L.F. Abbott and *Patrick Drew*, Brandeis University

**10:00-10:25 Localization of Moving Low-frequency Sounds**
Alla Borisyuk, Ohio State University

Friday, May 30

## MS75 (For Part II, see MS 86)

### Nonlinear Dynamics of Liquids with Interfaces

*8:30 AM-10:30 AM*

*Room: Maybird*

Liquids with interfaces are ubiquitous in nature and essential for many engineering processes. The liquid flows are subject to various instabilities which produce complex nonlinear dynamics. This minisymposium is devoted to different aspects of nonlinear interfacial phenomena including interfacial convection, phase transitions, viscous fingering, Faraday ripples, nonlinear Rayleigh-Taylor instability and others. The talks will present the physical explanation of the phenomena and will give a clear exposition of the mathematical analysis involved.

**Organizer: Alexander Nepomnyashchy**
*Technion - Israel Institute of Technology, Israel*

**8:30-8:55 Phase-change Phenomena and Connected Instabilities**
Ranga Narayanan, University of Florida

**9:00-9:25 Faraday Wave Pattern Selection via Multi-frequency Forcing**
*Mary C. Silber*, Northwestern University; Jeff B. Porter, University of Leeds, United Kingdom; and Chad M. Topaz, Duke University

**9:30-9:55 Unsteady Growth of Viscous Fingers**
Harry Swinney, W.D. McCormick, and *Mitchell Moore*, University of Texas, Austin

**10:00-10:25 Chains of Bubbles in Polymers: Unusual Outcome of Rayleigh-Taylor Instability**
Igor Kliakhandler, Michigan Technological University

Friday, May 30

# MS76

## Numerical Methods and Applications of Piecewise Smooth Systems

*8:30 AM-10:30 AM*

*Room: Superior B*

In recent years, much research effort has focused on dynamical systems which are nonsmooth or discontinuous. Such systems are used in many domains of applications. Examples include vibro-impacting machines in mechanical engineering and systems with friction, switching circuits in power electronics, physiological models, walking machines. More generally, all those systems which are intrinsically non-smooth on macroscopic time-scales. The focus of the minisyposium will be on the theoretical challenges related to the analysis of nonsmooth dynamical systems and their applications. The aim is to expound the latest advances in the development of theory, numerical methods and applications of these systems.

**Organizer: Martin Homer**
*University of Bristol, United Kingdom*

**8:30-8:55 Applications of Nonsmooth Dynamical Systems to Chaotic Communications**
Mario Di Bernardo, John Hogan, and *Martin Homer,* University of Bristol, United Kingdom

**9:00-9:25 SlideCont: An Auto97 driver for Sliding Bifurcation Analysis**
Fabio Dercole, Politecnico di Milano, Italy

**9:30-9:55 Analysis of Codimension-2 Sliding Bifurcations in a Representative Example of a Dry-friction Oscillator**
Piotr Kowalczyk, University of Bristol, United Kingdom

**10:00-10:25 Using Discontinuities for Stabilization of Recurrent Motions**
Petri T. Piiroinen, Royal Institute of Technology, Sweden

Friday, May 30

# MS77 (For Part I, see MS 52)

## PDE Methods in Multi-scale Flows

*8:30 AM-10:30 AM*

*Room: Superior A*

In recent years there has been a significant interest by the applied mathematical community in rigorous and PDE approach to multi-scale flows. In this mini-symposium the speakers will present their recent analytical and computational results concerning the global well-posedness, regularity, dynamical and statistical properties of solutions to this type of flows.

**Organizer: Edriss S. Titi**
*University of California, Irvine and Weizman Institute of Science, Israel*

**Organizer: Peter Constantin**
*University of Chicago*

**8:30-8:55 Which is the Domain of Validity of the Standart Diffusive Term $\mu\Delta u$?**
Didier Bresch, Universite Blaise Pascal-Clermont II, France

**9:00-9:25 Large-scale Vortices and Small-scale Waves in Fluid Dynamics**
Oliver Buhler, Courant Institute of Mathematical Sciences, New York University

**9:30-9:55 On Improved Bounds for Finite and Infinite Prandtl Number Rotating Convection**
Christopher Hallstrom, Brown University

**10:00-10:25 Global Well-posedness and Finite Dimensional Global Attractors for 3-D Planetary Geostrophic Models**
*Chongsheng Cao*, Los Alamos National Laboratory; Mohammed B. Ziane, University of Southern California; and Edriss S. Titi, University of California, Irvine

Friday, May 30

# MS78 (For Part I, see MS 55)

## Topological Methods in Dynamics

*8:30 AM-10:30 AM*

*Room: White Pine*

Dynamics which are genuinely nonlinear demand mathematical methods which are likewise nonlinear. Topological methods offer global results, robustness under large perturbations, and, increasingly, computability. This 2-part minisymposium features a broad collection of topological methods, with specific applications to, among others, elliptic and parabolic PDEs, fluid dynamics, and celestial mechanics. Since topological methods usually have high `overhead' in terms of learning the background mathematics (homology theory, symplectic topology, etc.), it is especially important to have a forum where the curious non-specialist can witness the state of the art.

**Organizer: Robert W. Ghrist**
*University of Illinois, Urbana-Champaign*

**Organizer: Konstantin Mischaikow**
*Georgia Institute of Technology*

**8:30-8:55 Some Topological Obstructions in 2D Inviscid Fluid Flows**
Philip Boyland, University of Florida

**9:00-9:25 Elliptic Boundary Value Problems from a Symplectic Point of View**
Jian Deng, California Institute of Technology

**9:30-9:55 Singular Boundary Value Problems Via the Conley Index**
Konstantin Mischaikow, Georgia Institute of Technology; and *Tomas Gedeon*, Montana State University

**10:00-10:25 Geometry of Basic Sets of Smale Flows**
Vadim Meleshuk, Georgia Institute of Technology

# Coffee Break

*10:30 AM-11:00 AM*

*Room: Golden Cliff*

Friday, May 30

# IP7

## Dynamic Features of Motor Networks and Behavior in Parkinson's Disease

*11:00 AM-12:00 PM*

*Room: Ballroom*

*Chair: G. Bard Ermentrout, University of Pittsburgh*

Oscillatory behavior is a ubiquitous, but yet not fully understood, feature of motor control networks. One of the behavioral manifestations of such oscillatory activity is the presence of tremors, which occur both in the normally functioning motor system and in a number of motor disorders, one of the best examples being the tremor associated with Parkinson's disease. The resurgence in recent years of microelectrode-guided surgical treatment of the motor symptoms of the disease has provided an opportunity to study the characteristics of neural activity within the basal ganglia and thalamus of parkinsonian patients. Our studies of the spatiotemporal dynamics of oscillatory activity in the basal ganglia and its relationship to tremor have provided insights into the types of networks in the brain that can support the dynamical features of the observed activity.

**Karen A. Sigvardt**
*University of California, Davis*

# Lunch Break

*12:00 PM-1:30 PM*

*Attendees on Their Own*

Friday, May 30

# IP8

## Computer Simulation of Dynamical Systems: The Good, the Bad, and the Awful

*1:30 PM-2:30 PM*

*Room: Ballroom*

*Chair: James A. Yorke, University of Maryland, College Park*

Excellent computer simulations are done for a purpose. The most valid purposes are to explore uncharted territory, resolve a well-posed scientific or technical question, or to make a design choice. Stand-alone modeling can serve the first purpose. The other two need a full integration of the modeling effort into a scientific or engineering program.

Some excellent work, much of it related to the Department of Energy Laboratories, is reviewed. Some less happy stories are recounted.

In the past, the most impressive work has involved multiple scales. Prediction in a world of multiple scales requires a first principles understanding based upon the intersection of theory, experiment and simulation.

* Supported in part by the ASCI/FLASH program at the University of Chicago

**Leo Kadanoff**
*University of Chicago*

# Intermission

*2:30 PM-2:45 PM*

Friday, May 30

# CP34

## Homoclinic Teeth, Bifurcations in Optics, and Unstable Periodic Orbits

*2:45 PM-3:25 PM*

*Room: Ballroom I*

*Chair: Sebastian Wieczorek, Sandia National Laboratories*

**2:45-3:00 Homoclinic Teeth and Excitability in Optically Driven Lasers**

*Sebastian Wieczorek*, Sandia National Laboratories; and Bernd Krauskopf, University of Bristol, United Kingdom

**3:05-3:20 Saddle-Node Hopf Bifurcation with Global Reinjection**

*Bart E. Oldeman*, Ohio State University; and Bernd Krauskopf, University of Bristol, United Kingdom

Friday, May 30

# CP35

## PDE Analysis for Fluid Flows and Water Waves

*2:45 PM-3:45 PM*

*Room: Ballroom II*

*Chair: Neil Balmforth, University of California, Santa Cruz*

**2:45-3:00 Diffusion-Limited Scalar Cascades**

*Neil Balmforth*, University of California, Santa Cruz; and William Young, University of California, San Diego

**3:05-3:20 Classification of Backward-Time Dynamics of the Space-Periodic Dissipative Pde's**

Radu Dascaliuc, Texas A&M University

**3:25-3:40 Higher Order Corrections to the KdV Approximation for Water Waves**

Eugene Wayne and *J. Douglas Wright*, Boston University

Friday, May 30

# CP36

## Nonlinear Dynamics in Transistors and Receivers

*2:45 PM-3:45 PM*

*Room: Ballroom III*

*Chair: Thomas Carroll, Naval Research Laboratory*

**2:45-3:00 Low Frequency Switching in a Transistor Amplifier**

Thomas Carroll, Naval Research Laboratory

**3:05-3:20 Split Personality of a Transistor**

Michal Odyniec, Signature BioScience Inc.

**3:25-3:40 Analysis of the Dynamics of a Beamforming Receiver with Coupled Nonlinear Oscillators**

Michael Gabbay and *Michael Larsen*, Information Systems Labs

Friday, May 30

# CP37

## Applications in Quantum Dynamics

*2:45 PM-3:45 PM*

*Room: Superior A*

*Chair: Anna Litvak-Hinenzon, University of Warwick, United Kingdom*

**2:45-3:00 Coupled Pairs of Methyl Groups and Tunneling Quantum Roto-Breathers**

Robert S. MacKay and *Anna Litvak-Hinenzon*, University of Warwick, United Kingdom

**3:05-3:20 Quantum Control Using Dynamical Systems Methods: Control of One and Two Interacting spin 1/2 Particles**

Domenico D'Alessandro, Iowa State University; and Igor Mezic and *Umesh Vaidya*, University of California, Santa Barbara

**3:25-3:40 Semiclassical Analysis of Long Wavelength, Multiphoton Processes**

Ron Fox and *Luz V. Vela-Arevalo*, Georgia Institute of Technology

Friday, May 30

# CP38

## Stochastic Differential Equations

*2:45 PM-3:25 PM*

*Room: Superior B*

*Chair: Eric W. Kuennen, University of Wisconsin, Stout*

**2:45-3:00 A Radial Continuum Equation for Three-Dimensional Rough Surface Growth**

*Eric W. Kuennen*, University of Wisconsin, Stout; and C Y Wang, Michigan State University

**3:05-3:20 Exponential Timestepping with Boundary Test for Stochastic Differential Equations**

Grant Lythe, University of Leeds, United Kingdom

Friday, May 30

# CP39

## Marginal Stability: Bose-Einstein Condensates and Optical Parametric Oscillators

*2:45 PM-3:45 PM*

*Room: Maybird*

*Chair: Zoi Rapti, University of Massachusetts, Amherst*

**2:45-3:00 On the Modulational Stability of Gross-Pittaevskii Type Equations in 1+1 Dimensions**

Panayotis Kevrekidis and *Zoi Rapti*, University of Massachusetts, Amherst; and Vladimir Konotop, Universidade de Lisboa, Portugal

**3:05-3:20 Attractive Bose-Einstein Condensates in a Double Well Potential**

*Russell K. Jackson*, Boston University; and Michael I. Weinstein, Bell Laboratories, Lucent Technologies

**3:25-3:40 Bursting Oscillations in Optical Parametric Oscillators**

Michel Nizette, Université Libre de Bruxelles, Belgium; *Marc Lefranc*, PhLAM/Université Lille I, France; Axelle Amon, Universite de Lille 1, France; and Thomas Erneux, Université Libre de Bruxelles

Friday, May 30

# CP40

## Coupled Oscillators

*2:45 PM-3:45 PM*

*Room: White Pine*

*Chair: Zonghua Liu, Arizona State University*

**2:45-3:00 Universal Scaling of Lyapunov Exponents in Coupled Chaotic Oscillators**

Ying-Cheng Lai and *Zonghua Liu*, Arizona State University; and Manuel A. Matias, Instituto Mediterraneo de Estudios Avanzados, Spain

**3:05-3:20 Synchronization for the Winfree Model of Coupled Nonlinear Oscillators: From Continuum to Discrete**

*D Dane Quinn*, University of Akron; and Joel Ariaratnam, Richard H. Rand, and Steven Strogatz, Cornell University

**3:25-3:40 Phase Synchronization of Chaos in Coupled Nonautonomous Oscillators**

Alexander N. Pisarchik, Centro de Investigaciones en Optica, Mexico

Friday, May 30

# CP41

## Topics in Fluid Dynamics - III

*2:45 PM-3:45 PM*

*Room: Magpie A*

*Chair: Andrew Salinger, Sandia National Laboratories*

**2:45-3:00 Stability Analysis of Large-Scale Incompressible Flow Systems**

T.J. Mountziaris, State University of New York, Buffalo; and John Shadid, Roger Pawlowski, Eric Phipps, and *Andrew Salinger*, Sandia National Laboratories

**3:05-3:20 Intermittency in a System of Self-Driven Particles**

*Cristian Huepe*, Northwestern University; and Maximino Aldana, University of Chicago

**3:25-3:40 Analysis of a Model Describing Filaments Growth**

Toru Maekawa, Toyo University, Japan; and William Derrick and *Leonid V. Kalachev*, University of Montana

Friday, May 30

# CP42

## Topics in Synchronization and Spatio-Temporal Chaos

*2:45 PM-3:45 PM*

*Room: Magpie B*

*Chair: Renate A. Wackerbauer, University of Alaska, Fairbanks*

**2:45-3:00 Transient Spatiotemporal Chaos**

*Renate A. Wackerbauer*, University of Alaska, Fairbanks; and Kenneth Showalter, West Virginia University

**3:05-3:20 Multiple Synchronization**

Mitrajit Dutta, University of New Hampshire

**3:25-3:40 Synchronizing Disparate Chaotic Systems Via Symbolic Dynamics**

Shawn Pethel, Krishna Myneni, and *Ned J. Corron*, US Army AMCOM

Friday, May 30

# CP43

## Topics in Mathematical Biology

*2:45 PM-3:45 PM*

*Room: Wasatch A*

*Chair: Meredith Betterton, University of Colorado, Boulder*

**2:45-3:00 Opening of DNA by Helicases**

Meredith Betterton, University of Colorado, Boulder

**3:05-3:20 Backfiring in Excitable Media and the Unfolding of a Heteroclinic Loop**

Jens D.M. Rademacher, University of Minnesota

**3:25-3:40 Asymmetric Partial Devil's Staircases**

Avinoam Rabinovitch and *Emanuel Yellin*, Ben-Gurion University of the Negev, Isreal

Friday, May 30

# CP44

## Instabilities in Optical Systems

*2:45 PM-3:45 PM*

*Room: Wasatch B*

*Chair: Serge Bielawski, PhLAM/ Université Lille I, France*

**2:45-3:00 A Laser with Parameters That Vary Slowly in Space: Bifurcation Analysis of the Eckhaus Instability**

Jerome Plumecoq, Marc Lefranc, Dominique Derozier, and *Serge Bielawski*, PhLAM/Université Lille I, France; Christophe Szwaj, PHLAM - Universite de Lille, France; and Thomas Erneux, Université Libre de Bruxelles

**3:05-3:20 Observation of Convective and Absolute Instabilities in An Optical System**

Pierre Glorieux and Eric Louvergneaux, Universite de Lille 1, France; and Gonzague Agez, Majid Taki, and *Christophe Szwaj*, PHLAM - Universite de Lille, France

**3:25-3:40 Transition from Hexagons to Spatio-Temporal Chaos in a Nonlinear Optical Cavity**

Damia Gomila and *Pere Colet*, IMEDEA, CSIC-Universitat de les Illes Balears, Spain

# Coffee Break

*3:45 PM-4:15 PM*

*Room: Golden Cliff*

Friday, May 30

# MS79 (For Part II, see MS 102)

## Low-dimensional Manifold Applications in Chemical-Kinetic Modeling

*4:15 PM-6:45 PM*

*Room: Ballroom II*

The modeling of important physical systems such as combustion and atmospheric chemistry involve a complex interplay between chemical kinetics and transport processes. These systems are often both computationally challenging and conceptually difficult because of this interplay. To meet these challenges it is useful to be able to reduce the dynamical systems describing the chemical kinetics in an accurate manner. The minisymposium presents talks which address this reduction using low-dimensional manifolds and related techniques.

**Organizer: Tasso J. Kaper**
*Boston University*

**Organizer: Michael J. Davis**
*Argonne National Laboratory*

**4:15-4:40 Intrinsic Low-Dimensional Manifolds - Recent Progress and Remaining**

Ulrich Maas, Stuttgart University, Germany

**4:45-5:10 Low-Dimensional Manifolds in Reaction-Diffusion Systems**

Sandeep Singh, University of Notre Dame; and Samuel Paolucci and *Joseph M. Powers*, University of Notre Dame, USA

**5:15-5:40 Slow Manifold for Bimolecular Association Mechanism**

Simon J. Fraser, University of Toronto, Canada

**5:45-6:10 Fundamentals of the Computational Singular Perturbation Method**

*Dimitris A. Goussis*, Patra, Greece; Harvey Lam, Princeton University; and Mauro Valorani and Francesco Creta, University of Rome, Italy

**6:15-6:40 Analysis of the CSP Reduction Method for Chemical Kinetics**

Antonios Zagaris, Boston University

Friday, May 30

# MS80

## Inertial Effects in Advection Dynamics

*4:15 PM-7:15 PM*

*Room: Magpie A*

The passive advection paradigm assumes that the advected tracers are point-like and take on the velocity of the fluid instantaneously. Depending on the characteristic size of the flow, on the actually finite size of the tracers --like e.g. in the case of spores, plankton, rain droplets, buoys or ballons-- and on the density mismatch between fluid and tracers, this might turn out to be an oversimplification. A basic inertial effect is that a pronounced deviation appears between the trajectory of the particle and of a neighbouring fluid element. The aim of the minisymposium is to overview recent results obtained in the field including the tendency of clustering (attractors), filamentation, transient chaos, and the effect of inertia on reactive processes in flows.

**Organizer: Tamas Tel**
*Eotvos University, Hungary*

**Organizer: Oreste Piro**
*Universidad de las Islas Baleares, Spain*

**4:15-4:40 The Dynamics of Finite Size Neutrally Buoyant Particles**

Oreste Piro, Universidad de las Islas Baleares, Spain

**4:45-5:10 Inertial Advection in Open Flows**

Zoltan Toroczkai, Los Alamos National Laboratory; and Izabella J. Benczik and *Tamas Tel*, Eotvos University, Hungary

**5:15-5:40 Inertial Advection in Three-dimensional Flows**

Idan Tuval, CSIC - Universidad de las Islas Baleares, Spain

**5:45-6:10 Inertial Particles in Slurry Flows**

*Nhat-Hang Duong*, Peko Hosoi and Troy Shinbrot, Rutgers University

**6:15-6:45 Boundary Effects on Chaotic Advection-Diffusion Chemical Reactions**

Micha Chertkov, Los Alamos National Laboratory

**6:45-7:10 Activity of Inertial Particles in Nonhyperbolic Open Flows**

Ying-Cheng Lai and *Adilson E. Motter*, Arizona State University; and Celso Grebogi, Universidade de Sao Paulo/USP, Brazil

Friday, May 30

# MS81

## Dynamics Near Structurally Stable Heteroclinic Cycles

*4:15 PM-7:15 PM*

*Room: Magpie B*

Homoclinic and heteroclinic cycles are common in low-dimensional dynamical systems, usually arising in global bifurcations but also occuring, in a structurally stable way, in some systems with symmetry. Studies of structurally stable heteroclinic cycles have focused on establishing conditions for their existence and asymptotic stability, and much less is known about the dynamics within networks of such cycles or in higher-dimensional systems.

This mini-symposium looks at some of the rich dynamics that occur near structurally stable heteroclinic cycles or networks of such cycles, or that result from their loss of stability or destruction via symmetry-breaking imperfections.

**Organizer: Edgar Knobloch**
*University of Leeds, United Kingdom*

**Organizer: Vivien Kirk**
*University of Auckland, New Zealand*

**4:15-4:40 A Mechanism for Switching in a Heteroclinic Network**
Mary C. Silber, Northwestern University; and *Vivien Kirk*, University of Auckland, New Zealand

**4:45-5:10 Loss of Stability of Cycling Chaos**
Peter Ashwin, University of Exeter, United Kingdom; and Alastair M. Rucklidge and *Rob Sturman*, University of Leeds, United Kingdom

**5:15-5:40 Heteroclinic Networks as Templates for Complex Dynamics**
Michael Field, University of Houston

**5:45-6:10 The 1:2 Spatial Resonance in Rayleigh-B'enard Convection**
Edgar Knobloch, University of Leeds, United Kingdom

**6:15-6:40 Heteroclinic Cycles and Kelvin-Helmholtz Instability in the Flow between Exactly Counter-rotating Disks**
Shihe Xin, Caroline Nore, Olivier Daube, and *Laurette S. Tuckerman*, LIMSI-CNRS, France

**6:45-7:10 Global Bifurcations and Heteroclinic Cycles in the Nonlocal Parametrically Driven NLS Equation**
Maria Higuera, Univ. Politecnica de Madrid, Spain; and Edgar Knobloch and *Jeff B. Porter*, University of Leeds, United Kingdom

Friday, May 30

# MS82 (For Part I, see MS 59)

## Asymptotic Analysis for Certain Geophysical and Hydrodynamical Flows - Part II

*4:15 PM-6:45 PM*

*Room: Ballroom I*

The minisymposium emphasizes recent progress in the asymptotic analysis of dissipative partial differential equations, especially those arising from fluid mechanical and geophysical models. The focus is mainly on: Long time behaviour of solutions, Asymptotic limits of partial differential equations in the presence of a small parameter, and boundary layer problems.

**Organizer: Mohammed B. Ziane**
*University of Southern California*

**Organizer: Igor Kukavica**
*University of Southern California*

**Organizer: Edriss S. Titi**
*University of California, Irvine and Weizman Institute of Science, Israel*

**4:15-4:40 The Two-dimensional Quasi-geostrophic Equation**
Jiahong Wu, Oklahoma State University

**4:45-5:10 On Time-asymptotics of the Domain of Spatial Analyticityfor Solutions of the Generalized KdV-equation**
Zoran Grujic, University of Virginia

**5:15-5:40 Numerically Determining Modes for the Lagrangian Averaged Navier-Stokes Alpha Model**
*Eric Olson*, University of Nevada, Reno; and Edriss S. Titi, University of California, Irvine

**5:45-6:10 Asymptotic Analysis of the Primitive Equations in Thin Domains**
Changbing Hu, Texas A&M University

**6:15-6:40 On the Backwards Behavior for the 2D Periodic Kelvin Filtered Navier-Stokes Equations**
Jesenko Vukadin, University of Wisconsin, Madison

Friday, May 30

# MS83 (For Part I, see MS 104)

## Locomotion and Control of Biomechanical Systems in a Fluid Environment

*4:15 PM-7:15 PM*

*Room: Ballroom III*

This minisymposium will focus on the locomotion and control of biomechanical systems moving in a fluid environment. The mathematics and modeling needed to tackle these complex, unsteady fluid-solid interaction problems requires a combined use of control theoretic techniques to implement and optimize locomotion strategies, fluid mechanics modeling to understand instabilities and dynamics of the ambient and shed wake vorticity, modeling of deformable structures to incorporate the robotic aspects of locomotion, and biomimetics to understand and mimic the the design principles and succesful strategies developed by nature. Talks will focus on control and modeling aspects of both swimming and flying.

**Organizer: Paul K. Newton**
*University of Southern California*

**Organizer: Jerrold E. Marsden**
*California Institute of Technology*

**4:15-4:40 Planar Propulsion through the Manipulation of Circulatory Flows**
Scott Kelly, University of Illinois, Urbana-Champaign

**4:45-5:10 Symmetry, Reduction and Swimming in a Perfect Fluid**
Jim Radford, California Institute of Technology

**5:15-5:40 Locomotion with Flexing and Oscillating Foils**
Richard Mason, California Institute of Technology

**5:45-6:10 Oscillatory Shape Actuation for Underwater Locomotion**
Kristi Morgansen, University of Washington, Seattle

**6:15-6:40 Adaptive Sampling Strategies for Fleets of Autonomous Underwater Gliders**
Eddie Fiorelli, Princeton University

**6:45-7:10 Dynamically Interacting Solid Body-Vorticity Field Systems**
Banavara Shashikanth, New Mexico State University

Friday, May 30

# MS84

## Models for Nerve Axons: Modeling, Analysis, and Computation

*4:15 PM-7:15 PM*

*Room: Wasatch A*

Biological systems have an inherently discrete nature. In systems where an action potential is propagated, this spatially discrete nature can and does effect the speed and quality of the propagating wave. Traveling wave fronts and pulses (single and multiple) are the focus of this session. The series of talks assembled here include the current functional analysis results for the underlying differential-difference equations to explicit applications such as bundles of mylinated nerve axons. The equations of interest can be loosely described as coupled systems of spatially discrete/continuous FitzHugh-Nagumo equations.

**Organizer: Erik Van Vleck**
*University of Kansas*

**Organizer: Christopher E. Elmer**
*New Jersey Institute of Technology*

**4:15-4:40 Coupled FitzHugh-Nagumo Equations**
Christopher E. Elmer, New Jersey Institute of Technology

**4:45-5:10 Traveling Waves for a Generalized FitzHugh-Nagumo Equation**
Weishi Liu, University of Kansas

**5:15-5:40 A Construction Technique for Heteroclinic Solutions to Continuous and Differential-Difference Damped Wave Equations**
Marianito Rodrigo, New Jersey Institute of Technology

**5:45-6:10 Computation of Modulated Waves in Reaction-diffusion Systems**
Bjorn Sandstede, Ohio State University

**6:15-6:40 Traveling Waves in Discrete FitzHugh-Nagumo Equations**
Erik Van Vleck, University of Kansas

**6:45-7:10 Computing Travelling Wave Solutions in a Neuronal Network**
Tony R. Humphries, McGill University, Canada

Friday, May 30

# MS85

## Neuroscience Modeling and Applications

*4:15 PM-6:45 PM*

*Room: Wasatch B*

This minisymposium will involve several active approaches to modeling of networks of neurons with a mind to bridging the gap between modeling and applications. Topics will range from theoretical studies of computational approaches to network dynamics (Kevrekidis, Siegel) to coupling and inhibition effects on neuronal networks (Lewis) to direct simulations of neuronal morphogenesis (van Pelt, Maskery) to applications of Mathematics to spinal cord repair (Shinbrot). We hope that this broad range of topics will serve both to survey different research approaches and to help integrate Mathematics and Neuroscience applications.

**Organizer: Troy Shinbrot**
*Rutgers University*

**4:15-4:40 Simulation of Growth Cone Pathfinding through Complex Environments**
Helen Buettner and *Susan Maskery*, Rutgers University

**4:45-5:10 TBA**

**5:15-5:40 Topology and Spinal Cord Repair**
Wise Young and *Troy Shinbrot*, Rutgers University

**5:45-6:10 Dendritic Effects in Networks of Spiking Neurons Connected by Inhibition and Electrical Coupling**
Tim Lewis, New York Univ/Center for Neural Sci and Courant Inst.

**6:15-6:40 A Coarse Computational Approach to Lattice Dynamics**
Joakim Moeller and Olof Runborg, Kungliga Tekniska Högskolan, Sweden; Panagiotis Kevrekidis, University of Massachusetts, Amherst; Kurt Lust, K.U.Leuven, Belgium; and *Yannis Kevrekidis*, Princeton University

**6:45-7:10 Modeling Dendritic Morphological Complexity Using Principles of Neural Development**
Jaap Van Pelt, Netherlands Institute for Brain Research, The Netherlands

Friday, May 30

# MS86 (For Part I, see MS 75)

## Nonlinear Dynamics of Liquids with Interfaces

*4:15 PM-7:15 PM*

*Room: Maybird*

Liquids with interfaces are ubiquitous in nature and essential for many engineering processes. The liquid flows are subject to various instabilities which produce complex nonlinear dynamics. This minisymposium is devoted to different aspects of nonlinear interfacial phenomena including interfacial convection, phase transitions, viscous fingering, Faraday ripples, nonlinear Rayleigh-Taylor instability and others. The talks will present the physical explanation of the phenomena and will give a clear exposition of the mathematical analysis involved.

**Organizer: Alexander Nepomnyashchy**
*Technion - Israel Institute of Technology, Israel*

**4:15-4:40 Nonlinear Dynamics of Interfacial Convection in Benard Layers**
Pierre Colinet, Université Libre de Bruxelles, Belgium

**4:45-5:10 Surface-tension-driven Convection in Small Vessels**
Marc Medale and Pierre Cerisier, Université de Provence, France

**5:15-5:40 Non-potential Effects in Marangoni Convection in Thin Liquid Films**
Alexander A. Golovin, Northwestern University

**5:45-6:10 Penta-hepta Defect Chaos in Hexagon Patterns with Rotation**
Hermann Riecke, Northwestern University; and Yuan-Nan Young, Stanford University

**6:15-6:40 Simulation of Benard-Marangoni Convection in a Vertical Magnetic Field**
Thomas Boeck, Université Pierre et Marie Curie, France

**6:45-7:10 Stability of Thermocapillary Flows**
Valentina Shevtsova, Université Libre de Bruxelles, Belgium; Oleg Shklyaev, Ilya Simanovskii, and *Alexander Nepomnyashchy*, Technion - Israel Institute of Technology, Israel; and Jean Claude Legros, Microgravity Research Center

Friday, May 30

# MS87

## Physical Applications of Interacting Particle Systems

*4:15 PM-7:15 PM*

*Room: White Pine*

Microscopic models and simulations, including molecular dynamics and Monte Carlo methods, are fundamental tools for obtaining quantitative insights into various physicochemical and biological processes. The microscopic interactions between individual particles underlying such methods are understood, but descriptions via these rules can be more complicated than desired or even computable. At large scales, self-organization and coherent behavior should be described by continuum equations, based on (typically non-equilibrium) statistical mechanics, which are in turn directly related to the microscopic interactions. In this minisymposium, we compare and contrast continuum modeling techniques for a variety of physical systems with interacting particles or microstructure.

**Organizer: Peter J. Mucha**
*Georgia Institute of Technology*

**Organizer: Markos A. Katsoulakis**
*University of Massachusetts, Amherst*

**4:15-4:40 Particle Distributions and Fluctuations in Sedimentation**
Peter J. Mucha, Georgia Institute of Technology

**4:45-5:10 Modeling Flows of Nematic Liquid Crystalline Polymers Using Kinetic Theories**
Qi Wang, Florida State University

**5:15-5:40 Dynamic Scaling Laws in Miscible Viscous Fingering**
Govind Menon, University of Wisconsin, Madison

**5:45-6:10 Bridging Length and Time Scales in Materials Modeling**
Dion Vlachos, University of Delaware

**6:15-6:40 Statistical Mechanics Models in Finite-temperature Micromagnetics**
Petr Plechac, University of Warwick, United Kingdom; and *Markos A. Katsoulakis*, University of Massachusetts, Amherst

**6:45-7:10 Discussion**
Peter J. Mucha, Georgia Institute of Technology

Friday, May 30

# MS88 (For Part II, see MS 99)

## Recent Results on the Fermi-Pasta-Ulam Problem

*4:15 PM-7:15 PM*

*Room: Superior A*

The FPU problem has a rich history. Originally proposed as a model for thermal diffusivity in solids, it was numerically studied with the expection of arriving at a statistical equilibrium. In fact, the original researchers discovered quasiperiodicity, which has subsequently been understood as a manifestation of integrability or near-integrability in the original parameter regime. On the other hand, there are parameter regimes for which the system does achieve equipartition. Both the statistical steady-state and the nearly-integrable approaches have inspired new mathematics and advanced the study of dynamical systems in general. In this minisymposium we will discuss both approaches to understanding FPU.

**Organizer: Joseph A. Biello**
*Rensselaer Polytechnic Institute*

**Organizer: R. E. Lee Deville**
*Rensselaer Polytechnic Institute*

**4:15-4:40 Resonances, Time-scales and Normal Forms for Chains of Oscillators**
Ferdinand Verhulst, University of Utrecht, Netherlands

**4:45-5:10 Birkhoff's Normal Form for the FPU Lattice**
Bob Rink, University of Utrecht, Netherlands

**5:15-5:40 Coherent Localized Structure Generation by Instabilities of the Invariant Manifolds of the FPU energy surface**
Stefano Ruffo, Universita' di Firenze, Italy

**5:45-6:10 Stability of Solitary Waves on FPU Lattices**
Robert L. Pego, University of Maryland, College Park

**6:15-6:40 On the Notion of Temperature in FPU Systems**
A. Carati, University of Milan, Italy

**6:45-7:10 On the Times of Relaxation to Equilibrium in FPU-Like Systems**
L. Galgani, University of Milan, Italy

Friday, May 30

# MS89 (For Part II, see MS 103)

## Transport by Chaotic Advection in Three Dimensional Flows and Maps

*4:15 PM-7:15 PM*

*Room: Superior B*

Transport is the study of the motion of ensembles of trajectories between regions of phase space. The efficiency of transport can be measured by mixing rates. Transport theory has applications to the motion of passive tracers in fluids, the calculation of particle confinement times in accelerators and plasma devices, chemical reaction rates, and the orbits of asteroids.

The dynamics of transport for two dimensional mappings is based on the partition of phase space into regions separated by codimension one partial barriers. Transport takes place through turnstiles or lobes in these barriers. Our understanding of transport in higher dimensional systems is much less well formulated. The talks in this mini-symposium will concentrate on the dynamics of three dimensional flows and mappings with the primary application to fluids. Dividing invariant sets in these systems should be two dimensional, and may arise for example as unstable manifolds for saddle equilibria or invariant tori, so a study of these structures is essential for the understanding of transport.

The first part of this session will be devoted to primarily theoretical and computational investigations. The basic mathematical theory that leads to understanding of transport in three-dimensional flows and maps in terms of geometric dynamical systems theory will be discussed. The second session in this minisymposium will be devoted to primarily experimental studies.

In this way we hope to achieve a rich interplay between the experimental facts and the underlying theory and to establish new frontiers for research in the subject of transport and mixing in three-dimensional flows.

**Organizer: James D. Meiss**
*University of Colorado, Boulder*

**Organizer: Igor Mezic**
*University of California, Santa Barbara*

**4:15-4:40 Barriers to Transport in 3-D Chaotic Flows**
Umesh Vaidya and *Igor Mezic*, University of California, Santa Barbara

Friday, May 30

## MS89

*continued*

**4:45-5:10 Blinking Rolls: Chaotic Advection in a 3D Flow with an Invariant**

James D. Meiss, Keith Julien, and *Paul Mullowney*, University of Colorado, Boulder

**5:15-5:40 Tangles Between Invariant Circles in Volume Preserving Maps**

Hector Lomeli, Instituto Tecnológico Autónomo de México; and *James D. Meiss*, University of Colorado, Boulder

**5:45-6:10 Weak Finite-time Melnikov Theory and Viscous Perturbations of 3D Euler Flow**

*Christopher Jones*, University of North Carolina; Igor Mezic, University of California, Santa Barbara; and Sanji Balasuriya, University of Sydney, Australia

**6:15-6:40 Unsteady Separation in Three-Dimensional Flows**

George Haller, Massachusetts Institute of Technology

**6:45-7:10 Multiscale Norm for Mixing and Application to Three-Dimensional Flows in Micromixers**

George Matthew, University of California, Santa Barbara

# Saturday, May 31

## Registration

*8:00 AM-4:30 PM*

*Room: Ballroom Lobby*

## Game Room

*8:00 AM-12:00 AM*

*Room: Eagles Nest*

Saturday, May 31

## MS90 (For Part I, see MS 68)

### Computing Manifolds: Techniques and Challenges

*8:30 AM-9:30 AM*

*Room: Ballroom I*

The invariant and implicitly defined manifolds often play a key role in the analysis of the underlying mathematical model. For example, in a given dynamical system, the stable and unstable manifolds of certain invariant sets essentially serve as a skeleton of the global dynamics of that system. On the other hand, implicitly defined manifolds appear when analyzing bifurcation phenomena.

The aim of this mini-symposium is to give an overview of the state of the art in methods for computing the manifolds. The speakers will mainly focus on the algorithmic aspects of the various approaches and emphasize both advantages and drawbacks of the respective methods.

**Organizer: Oliver Junge**

*University of Paderborn, Germany*

**Organizer: Alexander Vladimirsky**

*Cornell University*

**8:30-8:55 Periodic Orbits and their Invariant Manifolds in the Circular Restricted 3-Body Problem**

Sebius Doedel, Concordia University

**9:00-9:25 Computing Invariant Manifolds by Integrating Fattened Trajectories**

Michael Henderson, IBM T.J. Watson Research Center

Saturday, May 31

# MS91

## Coping with Coupling in Multivariate Time Series Analysis

*8:30 AM-10:30 AM*

*Room: Magpie A*

Motivated by recent research on synchronization of (chaotic) dynamical systems several methods have been proposed for deriving information about possible coupling or interaction of dynamical systems from multivariate time series. Such data analysis may provide, for example, better understanding of physiological or neurological systems. The goal of this minisymposium is to bring together groups that developed and evaluated different methods for detecting interrelations from data and/or applied these techniques to experimental data. To compare the different approaches a common data set will be made available for all authors of the minisymposium. One of the main goals will be to evaluate the reliability and limits of current detection methods.

**Organizer: Ulrich Parlitz**
*University of Goettingen, Germany*

**8:30-8:55 Detecting Interrelations Between Time Series Using Randomized Delay Embedding**
Ulrich Parlitz, University of Goettingen, Germany

**9:00-9:25 Discriminating Linear Correlation and Nonlinear Interdependence by Means of Bivariate Surrogate Techniques**
Alexander Kraskov, Harald Stoegbauer, and *Ralph Andrzejak*, John von Neumann Institute, Germany; Florian Mormann and Klaus Lehnertz, University of Bonn, Germany; Thomas Kreuz, John von Neumann Institute, Germany/University of Bonn, Germany; and Peter Grassberger, NIC, FZ Juelich, Germany

**9:30-9:55 Identification of Coupling Direction from Bivariate Data**
Laura Cimponeriu and Anastasios Bezerianos, University of Patras, Greece; Michael Rosenblum and *Arkady Pikovsky*, University of Potsdam, Germany; Boris Bezruchko and Vladimir Ponomarenko, Institute of Radio-Engineering and Electronics, Russian Academy of Sciences, Russia; and Andreas Patzak and Ralf Mrowka, Humboldt University at Berlin, Germany

**10:00-10:25 Dimensionality Reconstruction of Coupled Subsystems from Multivariate Data and Application to Space Time Chaos Characterization**
Diego L. Valladares, Universidad de Navarra, Spain; Luc Pastur and *Stefano Boccaletti*, Istituto Nazionale di Ottica Applicata, Italy; and Louis M. Pecora and Tom Carroll, Naval Research Laboratory

Saturday, May 31

# MS92 (For Part I, see MS 69)

## Dynamics of Complex Networks - Part II

*8:30 AM-10:30 AM*

*Room: Magpie B*

Complex networks of dynamical elements often appear as natural models for a variety of real-world systems, such as social networks, neural networks, and the Internet. The rapid development over the recent years has shown that many examples of networked systems share common topological characteristics, such as small-world and scale-free properties, and that the dynamics of the network is strongly affected by them. The speakers of this minisymposium will explore this interplay between the topology and the dynamics of complex networks in several different contexts, including growing networks, epidemic processes, attack vulnerability, election dynamics, and synchronization.

**Organizer: Takashi Nishikawa**
*Arizona State University*

**Organizer: Adilson E. Motter**
*Arizona State University*

**8:30-8:55 Timing Patterns in Computer Virus Spread**
larry liebovitch, Florida Atlantic University; and *Ira B. Schwartz,* Naval Research Laboratory

**9:00-9:25 The Dynamics of Proportional Elections**
Dietrich Stauffer, University of Cologne, Germany; *Americo Bernardes*, Universidade Federal de Ouro Preto, Brazil; and Janos Kertesz, Budapest University of Technology and Economics, Hungary

**9:30-9:55 Emergence of Complex Dynamics in Simple Signaling Networks**
*Luis Amaral,* Northwestern University; Lewis Lipsitz and Ary Goldberger, Harvard Medical School; and Albert Diaz-Guilera, Universitat de Barcelona, Spain

**10:00-10:25 On the Origin of the Small-world Phenomenon**
Ying-Cheng Lai, Takashi Nishikawa, and *Adilson E. Motter*, Arizona State University

Saturday, May 31

## MS93

### Forced and Coupled Oscillators

*8:30 AM-10:30 AM*

*Room: Ballroom II*

The study of forced and coupled nonlinear oscillators has a long history in nonlinear dynamics and is relevant for applications in numerous areas. In this minisymposium, we present four such applications to illustrate their importance. These are the generation of coherent radiative power from the coupling of microwave oscillators, the dynamics of circadian rhythms in the chemistry of the eyes, the community structure of networks, and modulated amplitude waves in Bose-Einstein condensates.

**Organizer: Mason A. Porter**
*Georgia Institute of Technology*

**8:30-8:55 Modulated Amplitude Waves in Bose-Einstein Condensates**
Predrag Cvitanovic and *Mason A. Porter*, Georgia Institute of Technology

**9:00-9:25 Approximating a Time Delay in Coupled van der Pol Oscillators**
Stephen Wirkus, California Polytechnic State University, Pomona

**9:30-9:55 Dynamics of Two van der Pol Oscillators Coupled via a Bath**
Erika T. Camacho, Cornell University

**10:00-10:25 The Community Structure of Networks**
Mark Newman, University of Michigan/ Santa Fe Institute; and *Michelle Girvan*, Cornell University/Santa Fe Institute

Saturday, May 31

## MS94 (For Part I, see MS 70)

### Frontiers in Chemotaxis Modeling - Part II

*8:30 AM-10:30 AM*

*Room: Ballroom III*

Chemotaxis, or more general chemosensitive movement, describes the active orientation of individuals or populations along chemical signal. A detailed investigation of the pattern forming properties of chemotaxis is necessary to understand aggregations in slime molds, localization and polarization in an embryo, trace following of leukocytes, mechanisms for angiogenesis and tumor development, etc. Models for chemotaxis are generally framed as continuous models in the form of partial (integro-) differential equations, or as individual-based computer models, such as cellular automata or stochastic models. Recently many results on both types of models have been obtained and many mechanisms are understood quite well. This makes a minisymposium on this topic very timely.

The purpose of this Minisymposium is, first to present the current state of the art in chemotaxis modeling, secondly to compare different model types, and finally to identify evident and important new questions and to discuss new approaches and new ideas. Purpose: The theory of Dynamical Systems is the major tool in the study of chemotaxis models. On the other hand, the variety of patterns in chemotaxis models has initiated great interest from the theoretical point of view. For example the study of finite time blow-up, or of ultra long transients, has stimulated new ideas in Dynamical System theory.

**Organizer: Hans G. Othmer**
*University of Minnesota, Minneapolis*

**Organizer: Thomas J. Hillen**
*University of Alberta, Canada*

**8:30-8:55 Pseudostructures: Ultra-long Transients in Chemotaxis Model**
Alex Potapov, University of Alberta, Canada

**9:00-9:25 TBA**

**9:30-9:55 Aggregation in Keller-Segel Models**
J.J.L. Velazquez, Universidad de Complutense de Madrid, Spain

**10:00-10:25 Blow-up in Hyperbolic Models for Chemotaxis**
Thomas J. Hillen, University of Alberta, Canada

Saturday, May 31

## MS95 (For Part I, see MS 72)

### Localized and Synchronized Patterns Via Local and Non-Local Interactions - Part II

*8:30 AM-10:30 AM*

*Room: Wasatch A*

The minisymposium brings together modeling, analytical, computational and experimental studies in which different types of interactions are found to influence pattern dynamics. Key dynamical features, such as singular perturbations, canards, memory and delay, also contribute to localization, clustering, and synchronization. The talks compare and contrast different mechanisms which lead to various non-trivial behaviors. Part I focuses on spikes in reaction-diffusion systems, bump-type solutions in integro-differential equations, and firing patterns in coupled neurons. Part II concentrates on global coupling, with and without delay, and mechanisms leading to clustering and localization in models and experiments of chemical reactions.

**Organizer: Horacio Rotstein**
*Boston University*

**Organizer: Rachel Kuske**
*University of British Columbia, Canada*

**8:30-8:55 Controlling Turbulence and Pattern Formation in a Surface Chemical Reaction**
Matthias Bertram, Fritz-Haber-Institute, Berlin; and Gerhard Ertl, Alexander S. Mikhailov, Harm H. Rotermund, and *Carsten Beta*, Fritz-Haber Institut, Germany

**9:00-9:25 Cluster Formation and Localization in the Globally Forced BZ Reaction and Other Reaction-Diffusion Systems**
Milos Dolnik, Lingfa Yang, Anatol M. Zhabotinsky, Vladimir K. Vanag, and *Irving R. Epstein*, Brandeis University

**9:30-9:55 Localization of Oscillations in a Mathematical Model of the BZ Reaction**
Horacio Rotstein, Boston University

**10:00-10:25 Modulation Equations for Localized Patterns Away from Criticality**
Rachel Kuske, University of British Columbia, Canada

Saturday, May 31

# MS96 (For Part I, see MS 74)

## Neural Dynamics and Behavior

### *8:30 AM-10:30 AM*

*Room: Wasatch B*

A fundamental challenge in systems neuroscience is to understand how activity in neural circuits gives rise to behavior in animals. Recent advances in experimental recording techniques and data analysis have allowed neuroscientists to correlate specific neuronal network activity with specific behaviors. However, in most circumstances, the biophysical mechanisms underlying the neuronal activity remain unclear. Mathematical modeling is helping to uncover these mechanisms, and it could provide further insight into the behavior of the animal.

In this minisymposium, speakers will discuss biophysical mathematical models of various neural systems (sensorimotor, motor, communication, and sound localization), emphasizing the link between behavior and the underlying physiology.

**Organizer: Alla Borisyuk**
*Ohio State University*

**Organizer: Timothy J. Lewis**
*New York Univ/Center for Neural Sci and Courant Inst.*

**8:30-8:55 Response Dynamics and Phase Oscillators in the Brainstem**
Jeff Moehlis, Phil Holmes, and *Eric T. Brown*, Princeton University

**9:00-9:25 Dendritic Hysteresis Increases the Robustness of Fixations in a Model Neural Integrator**
Sebastian Seung, Joseph Levine, and *Mark Goldman,* Massachusetts Institute of Technology; and Guy Major and David Tank, Princeton University

**9:30-9:55 Synchronization in Globally Inhibitory Networks: Modeling the Sharp Wave-associated Ripple**
Amitabha K. Bose, New Jersey Institute of Technology; and *Steve Kunec*, Boston University

**10:00-10:25 Coupling within Oscillatory Networks: Theory and Experiment**
Karen A. Sigvardt, University of California, Davis

Saturday, May 31

# MS97

## Nonlinear Dynamics, Control and Condition Monitoring

### *8:30 AM-10:30 AM*

*Room: White Pine*

This mimisymposium is devoted to recent advances in applied nonlinear dynamics, control and condition monitoring of engineering systems and structures as it can be easily noticed that more and more emphasis is laid on the practical applications of the nonlinear dynamics theory. The proposed selection of problems include chaotic dynamics of a rotor system with a snubber ring, dynamics and control of vibro-impact drilling, harmonic balance method and phase shift adjustment in ground moling and bifurcation based sensing. All presentations will have combinations of theoretical and experimental results.

**Organizer: Marian Wiercigroch**
*University of Aberdeen, United Kingdom*

**8:30-8:55 Nonlinear Dynamics and Control of Jeffcott Rotor**
Evgueni Karpenko, King's College; and *Marian Wiercigroch*, University of Aberdeen, United Kingdom

**9:00-9:25 Vibro-Impact Systems Dynamics**
Marian Wiercigroch and *Ekaterina Pavlovskaia*, University of Aberdeen, United Kingdom

**9:30-9:55 Harmonic Balance and Phase Shift Adjustment in Ground Moling**
Ko-Choong Woo, University of Nottingham in Malaysia

**10:00-10:25 Probing a Chaotic Channel by Means of Signal Control**
Alan Fenwick, QinetiQ, United Kingdom

Saturday, May 31

# MS98 (For Part II, see MS 101)

## Prediction of Geophysical Dynamical Systems

### *8:30 AM-10:30 AM*

*Room: Maybird*

The talks in these sessions will explore some of the issues involved in modeling dynamical systems related to weather prediction and other geophysical flows. Several speakers will address the issue of data assimilation: how to determine the relevant initial conditions for such processes.

**Organizer: James A. Yorke**
*University of Maryland, College Park*

**Organizer: Eric J. Kostelich**
*Arizona State University*

**8:30-8:55 Exploiting Local Low Dimensionality of Atmospheric Dynamics for Efficient Ensemble Kalman Filtering**
Edward Ott, University of Maryland, College Park

**9:00-9:25 TBA**

**9:30-9:55 Effective Adaptive Sampling of Mega-Dimensional Chaos**
Craig Bishop, Naval Research Laboratory

**10:00-10:25 Atmospheric Data Assimilation: New Kalman-Filtering Techniques Using Ensembles**
Thomas Hamill, National Oceanic and Atmospheric Administration

Saturday, May 31

# MS99 (For Part I, see MS 88)

## Recent Results on the Fermi-Pasta-Ulam Problem - Part II

*8:30 AM-10:30 AM*

*Room: Superior A*

The FPU problem has a rich history. Originally proposed as a model for thermal diffusivity in solids, it was numerically studied with the expection of arriving at a statistical equilibrium. In fact, the original researchers discovered quasiperiodicity, which has subsequently been understood as a manifestation of integrability or near-integrability in the original parameter regime. On the other hand, there are parameter regimes for which the system does achieve equipartition. Both the statistical steady-state and the nearly-integrable approaches have inspired new mathematics and advanced the study of dynamical systems in general. In this minisymposium we will discuss both approaches to understanding FPU.

**Organizer: Joseph A. Biello**
*Rensselaer Polytechnic Institute*

**Organizer: R. E. Lee Deville**
*Rensselaer Polytechnic Institute*

**8:30-8:55 Weak Turbulence and the Stages of Energy Transfer in α-FPU**
Yuri V. Lvov, Peter R. Kramer, and *Joseph A. Biello*, Rensselaer Polytechnic Institute

**9:00-9:25 Transitions and Time Scales to Equipartition in Oscillator Chains: from the FPU to the Klein-Gordon chain**
Jayme De Luca, Universidade Federal de Sao Carlos, Brazil

**9:30-9:55 Simulating Disordered Extended Lattice Systems on Finite Domain**
Emilio Castronovo, Yuri V. Lvov, Joseph A. Biello, and *Peter R. Kramer*, Rensselaer Polytechnic Institute

**10:00-10:25 Symplectic Structure of FPU Equations and Global-in-time Stability of Solitary Waves**
Gero Friesecke, University of Warwick, United Kingdom

Saturday, May 31

# MS100 (For Part I, see MS 53)

## Renormalization Group and Asymptotics for Differential Equations

*8:30 AM-10:00 AM*

*Room: Superior B*

Perturbation theory and asymptotic analysis play a fundamental role in applied mathematics and dynamical systems theory. Familiar techniques for ordinary differential equations include the method of multiple scales, averaging theory, asymptotic matching, center manifold theory, and WKB, just to name a few. In the last decade, the renormalization group method was proposed as a unified framework for singular and reductive perturbation problems. The RG method improves the global behavior of ``naive" perturbation expansions by renormalizing secular divergences. This minisymposium focuses on recent developments of RG, as well as its theoretical underpinnings and applications.

**Organizer: Anthony Harkin**
*Harvard University*

**8:30-8:55 Renormalization and Geostrophic Asymptotics in Geophysical Fluid Dynamics**
Djoko Wirosoetisno, Indiana University

**9:00-9:25 Renormalization Method for the Asymptotic Solution of Weakly Nonlinear Vector Systems**
Blessing Mudavanhu, American International Group, Inc.

**9:30-9:55 Normal Form Theory and Asymptotics for Weakly Nonlinear ODE's**
Lee Deville, Rensselaer Polytechnic Institute; Tasso J. Kaper, Boston University; Kreso Josic, University of Houston; and *Anthony Harkin*, Harvard University

# Coffee Break

*10:30 AM-11:00 AM*

*Room: Golden Cliff*

Saturday, May 31

# IP9

## Electro-Manipulation of Particles in Fluidic Devices

*11:00 AM-12:00 PM*

*Room: Ballroom*

*Chair: Edriss S. Titi, University of California, Irvine and Weizmann Institute of Science, Israel*

Particles suspended in a fluid and subjected to an electric field exhibit motion when the particles and the fluid have different electrical properties. Such motion, referred to as "dielectrophoresis", has recently attracted much attention for the controlled manipulation and separation of micrometer and submicrometer-sized particles such as biological cells, microorganisms and macromolecules. Despite numerous applications ranging from biotechnology to materials processing, the development of this field into new technologies has been hindered by our lack of understanding of the various physical phenomena involved. In this presentation, we propose novel direct simulations of electro-rheological suspensions based on the Distributed Lagrange Multiplier method (DLM) in which the flow-particle interactions are accounted for exactly, and the mutual electrostatic forces acting on the polarized particles are represented by means of the point-dipole approximation. Numerical simulations will be presented for both uniform and spatially varying electric fields in the case of imposed and no imposed flow, and compared with experimental results.

**Nadine Aubry**
*New Jersey Institute of Technology*

# Lunch Break

*12:00 PM-1:30 PM*

*Attendees on Their Own*

Saturday, May 31

# IP10

## Singular Asymptotics for Nonlinear Dispersive Waves

*1:30 PM-2:30 PM*

*Room: Ballroom*

*Chair: Jared Bronski, University of Illinois, Urbana-Champaign*

A common feature of nonlinear wave propagation in many physical systems is an instability causing long wavepackets to break into pulses now called solitons (e.g., the Benjamin-Feir instability of water-waves and the modulational instability of fiber optics). In some contexts ( e.g., in dispersion-shifted fibers), the solitons are small compared to the size of a typical wavepacket. Thus, wavepackets decay by emitting an enormous number of solitons. We want to make whatever predictions we can about the asymptotic behavior of this complicated process in the limit when the scale ratio goes to zero.

Effectiveness of numerical computation limited in such problems by stiffness, i.e., relevant features occur on widely separated scales. Approaches based on formal expansions sometimes lend insight, but equally often yield apparently nonsensical model equations for which the initial-value problem is ill-posed.

This presentation will describe these phenomena in some detail, and will show how the asymptotic behavior can be analyzed precisely for integrable nonlinear wave equations.

**Peter D. Miller**
*University of Michigan, Ann Arbor*

# Intermission

*2:30 PM-2:45 PM*

Saturday, May 31

# CP45

## Applications in Economics

*2:45 PM-3:25 PM*

*Room: Ballroom I*

*Chair: Ellina V. Grigorieva, Texas Woman's University*

**2:45-3:00 Two Parameter Optimal Control of a Nonlinear Dynamical Microeconomic Model**
Eugene Khailov, Moscow State University, Russia; and *Ellina V. Grigorieva*, Texas Woman's University

**3:05-3:20 Nonlinear Dynamical Model of Small Group Decision Making**
Michael Gabbay, Information Systems Labs

Saturday, May 31

# CP46

## Applications in Mechanical and Electromagnetic Systems

*2:45 PM-3:45 PM*

*Room: Ballroom II*

*Chair: Timothy J. Burns, National Institute of Standards and Technology*

**2:45-3:00 Receptance Coupling for High-Speed Machining Dynamics Prediction**
*Timothy J. Burns*, National Institute of Standards and Technology; and Tony Schmitz, University of Florida

**3:05-3:20 Modelling and Dynamic Response of a Damper with Relief Valve**
Richard D. Eyres, University of Bristol, United Kingdom

**3:25-3:40 On Numerical Analysis, Normalization of Fields in Mis-Aligned Conductors Or Shells**
Kumud S. Altmayer, University of Arkansas, Pine Bluff

Saturday, May 31

# CP47

## Applications to Mechanics, Solids, and Elastic Media

*2:45 PM-3:45 PM*

*Room: Ballroom III*

*Chair: Patrick Wilber, University of Akron*

**2:45-3:00 Identification of Young's Elasticity's Modulus**

Rik Pintelon, Schoukens Johan, and *Kathleen De Belder*, Vrije Universiteit Brussel, Belgium

**3:05-3:20 Longterm Dynamics for Equations Modeling Nonuniform Deformable Bodies with Heavy Rigid Attachments**

Patrick Wilber, University of Akron

**3:25-3:40 Monodromy in the Resonant Swing Spring**

Andrea Giacobbe and Richard Cushman, University of Utrecht, The Netherlands; and *Holger R. Dullin*, Loughborough University, United Kingdom

Saturday, May 31

# CP48

## Control and Parameter Estimation/Observability

*2:45 PM-3:45 PM*

*Room: Superior A*

*Chair: Inam Belmouhoub, ENSEA, France*

**2:45-3:00 Quadratic Equivalence: An Efficient Tool For Observability Analysis**

Mohamed Djemaï, Jean-Pierre Barbot, and *Inam Belmouhoub*, ENSEA, France

**3:05-3:20 Nonlinear Control of Engine Speed and Air-Fuel Ratio in Automotive Systems**

Reza Banirazi, Iran Water & Power Company, Iran

**3:25-3:40 On the Estimate of the Stochastic Layer Width for a Model of Tracer Dynamics**

Fred Feudel, University of Potsdam, Germany; and Miguel A. Sanjuan, Jose Baltana, and *Jose Trueba*, Universidad Rey Juan Carlos, Spain

Saturday, May 31

# CP49

## Lattice Models in Applications

*2:45 PM-3:25 PM*

*Room: Superior B*

*Chair: Timothy K. Callahan, Arizona State University*

**2:45-3:00 Pattern Formation on Three-Dimensional Superlattices**

Timothy K. Callahan, Arizona State University

**3:05-3:20 Scaling Laws for Damage Evolution in Disordered Materials: Numerical Aspects**

Srdan Simunovic and *Phani K. Nukala*, Oak Ridge National Laboratory

Saturday, May 31

## CP50

### Swarming, Population Dynamics, and Stochastic PDE

*2:45 PM-3:25 PM*

*Room: Wasatch A*

*Chair: David F. Miller, Wright State University*

**2:45-3:00 Domain Optimization for Stochastic Diffusions**

David F. Miller, Wright State University

**3:05-3:20 Positive Solutions Of Three-Point Nonlinear Second Order Boundary Value Problem**

Youssef N. Raffoul, University of Dayton

Saturday, May 31

## CP51

### Topics in Bifurcation Theory and its Applications

*2:45 PM-3:25 PM*

*Room: Wasatch B*

*Chair: Rebecca B. Hoyle, University of Surrey, United Kingdom*

**2:45-3:00 Bifurcation with Icosahedral Symmetry**

Rebecca B. Hoyle, University of Surrey, United Kingdom

**3:05-3:20 Transition to High-Dimensional Chaos Through a Global Bifurcation**

*Manuel Matías*, Instituto Mediterraneo de Estudios Avanzados, Spain; and Diego Pazó, Universidad de Santiago de Compostela, Spain

Saturday, May 31

## CP52

### Topics in Dynamical Systems with Randomness

*2:45 PM-3:25 PM*

*Room: Magpie A*

**2:45-3:00 Uncertainty Analysis of Dynamical Systems**

Mark R. Myers and *Thordur Runolfsson*, United Technologies Research Center; and Igor Mezic, University of California, Santa Barbara

**3:05-3:20 Direction of Coupling from Phases of Interacting Oscillators: An Information-Theoretic Approach**

Milan Palus, Academy of Sciences of the Czech Republic

Saturday, May 31

# CP53

## Topics in Physics and Biophysics

*2:45 PM-3:25 PM*

*Room: Magpie B*

*Chair: Adam S. Landsberg, The Claremont Colleges*

**2:45-3:00 A Study of Correlations in Systems of Coupled Soc Automata**

Eric Friedman, Cornell University; *Adam S. Landsberg*, The Claremont Colleges; and Reuben Gann and Jessica Venable, Claremont McKenna College

**3:05-3:20 Hybrid Systems Forming Strange Billiards**

Ulrich Parlitz and *Karsten Peters*, University of Goettingen, Germany

Saturday, May 31

# CP54

## Topics in Turbulence and Hamiltonian Dynamics

*2:45 PM-3:45 PM*

*Room: White Pine*

*Chair: Michael D. Graham, University of Wisconsin, Madison*

**2:45-3:00 Coherent Structures and Turbulent Drag Reduction in Viscoelastic Flows**

Philip Stone and *Michael D. Graham*, University of Wisconsin, Madison

**3:05-3:20 Local Stable Manifold for the Bidirectional Discrete-Time Dynamics**

Carmeliza L. Navasca, University of Waterloo, Canada

**3:25-3:40 Periodic Driving of Turbulence**

Andre Ferreira, Murilo S. Baptista, and *Ibere L. Caldas*, University of Sao Paulo, Brazil; and Maria Vittoria Heller, Universidade de Sao Paulo, Brazil

# Coffee Break

*3:45 PM-4:15 PM*

*Room: Golden Cliff*

Saturday, May 31

# MS101 (For Part I, see MS 98)

## Prediction of Geophysical Dynamical Systems

*4:15 PM-6:15 PM*

*Room: Maybird*

The talks in these sessions will explore some of the issues involved in modeling dynamical systems related to weather prediction and other geophysical flows. Several speakers will address the issue of data assimilation: how to determine the relevant initial conditions for such processes.

**Organizer: James A. Yorke**
*University of Maryland, College Park*

**Organizer: Eric J. Kostelich**
*Arizona State University*

**4:15-4:40 Effects of Rotation and Lorentz Forces on Turbulent Geophysical Flows**

Daniel P. Lathrop, University of Maryland, College Park

**4:45-5:10 Competing Theoretical Frameworks for Atmospheric Variability: Quasi-geostrophic Turbulence vs Linear Stochastic Dynamics**

Joseph Tribbia, National Center for Atmospheric Research

**5:15-5:40 Moist Convection in a Three Layer Shallow Water Model**

Joseph A. Zehnder, Arizona State University

**5:45-6:10 Multiscale Variability of Shear Stratified Turbulence Around A Jet Stream**

K.L. Tse, B. Joseph, B. Nicolaenko, and *A. Mahalov*, Arizona State University

Saturday, May 31

## MS102 (For Part I, see MS 79)

## Low-dimensional Manifold Applications in Chemical-Kinetic Modeling - Part II

*4:15 PM-6:45 PM*

*Room: Ballroom II*

The modeling of important physical systems such as combustion and atmospheric chemistry involve a complex interplay between chemical kinetics and transport processes. These systems are often both computationally challenging and conceptually difficult because of this interplay. To meet these challenges it is useful to be able to reduce the dynamical systems describing the chemical kinetics in an accurate manner. The minisymposium presents talks which address this reduction using low-dimensional manifolds and related techniques.

**Organizer: Tasso J. Kaper**
*Boston University*

**Organizer: Michael J. Davis**
*Argonne National Laboratory*

**4:15-4:40 Analysis of Multidimensional Reacting Flow with CSP**

*Habib N. Najm*, Sandia National Laboratories; Dimitris A. Goussis, Patra, Greece; and Mauro Valorani and Francesco Creta, University of Rome, Italy

**4:45-5:10 The Reduction of Complex Atmospheric Chemical Models Using Time-Scale Based**

Alison Tomlin, University of Leeds, United Kingdom

**5:15-5:40 Low Dimension Manifolds for Aggregation Kinetics: An Alternative to Scaling Theories**

Rex Skodje, University of Colorado, Boulder

**5:45-6:10 Qualitative Applications of Invariant Manifold Theory in Biochemical Modeling**

Marc Roussel, University of Lethbridge, Canada

**6:15-6:40 Some Applications of Low-dimensional Manifolds to Problems in Chemical Kinetics**

Michael J. Davis, Argonne National Laboratory

Saturday, May 31

## MS103 (For Part I, see MS 89)

## Transport by Chaotic Advection in Three Dimensional Flows and Maps - Part II

*4:15 PM-6:45 PM*

*Room: Superior B*

Transport is the study of the motion of ensembles of trajectories between regions of phase space. The efficiency of transport can be measured by mixing rates. Transport theory has applications to the motion of passive tracers in fluids, the calculation of particle confinement times in accelerators and plasma devices, chemical reaction rates, and the orbits of asteroids.

The dynamics of transport for two dimensional mappings is based on the partition of phase space into regions separated by codimension one partial barriers. Transport takes place through turnstiles or lobes in these barriers. Our understanding of transport in higher dimensional systems is much less well formulated. The talks in this mini-symposium will concentrate on the dynamics of three dimensional flows and mappings with the primary application to fluids. Dividing invariant sets in these systems should be two dimensional, and may arise for example as unstable manifolds for saddle equilibria or invariant tori, so a study of these structures is essential for the understanding of transport.

The first part of this session will be devoted to primarily theoretical and computational investigations. The basic mathematical theory that leads to understanding of transport in three-dimensional flows and maps in terms of geometric dynamical systems theory will be discussed. The second session in this minisymposium will be devoted to primarily experimental studies.

In this way we hope to achieve a rich interplay between the experimental facts and the underlying theory and to establish new frontiers for research in the subject of transport and mixing in three-dimensional flows.

**Organizer: James D. Meiss**
*University of Colorado, Boulder*

**Organizer: Igor Mezic**
*University of California, Santa Barbara*

**4:15-4:40 Experimental and Computational Studies of Chaotic Mixing in 3D Vortical Flows**

Fotis Sotiropoulos, Georgia Institute of Technology

**4:45-5:10 Experimental Studies of Chaotic Mixing in Vortex Flows**

Tom Solomon, Bucknell University

**5:15-5:40 3D Flow Instabilities in Granular Suspensions**

Anette Hosoi, Massachusetts Institute of Technology; and Nhat-Hang Duong and *Troy Shinbrot*, Rutgers University

**5:45-6:10 Mixing and Transport in Taylor Couette Flows**

*Richard M. Lueptow*, Northwestern University; Alp Akonur, Baxter Healthcare Corp., Round Lake, IL; and Steven Wereley, Purdue University

**6:15-6:40 Experiments and Numerical Studies of 3-D Chaotic Flows in a Micromixer**

Igor Mezic, Carl Meinhart, Sophie Loire, and *F. Bottausci*, University of California, Santa Barbara

Saturday, May 31

# MS104 (For Part I, see MS 83)

## Locomotion and Control of Biomechanical Systems in a Fluid Environment - Part II

*4:15 PM-6:45 PM*

*Room: Ballroom III*

This minisymposium will focus on the locomotion and control of biomechanical systems moving in a fluid environment. The mathematics and modeling needed to tackle these complex, unsteady fluid-solid interaction problems requires a combined use of control theoretic techniques to implement and optimize locomotion strategies, fluid mechanics modeling to understand instabilities and dynamics of the ambient and shed wake vorticity, modeling of deformable structures to incorporate the robotic aspects of locomotion, and biomimetics to understand and mimic the the design principles and succesful strategies developed by nature. Talks will focus on control and modeling aspects of both swimming and flying.

**Organizer: Paul K. Newton**
*University of Southern California*

**Organizer: Jerrold E. Marsden**
*California Institute of Technology*

**4:15-4:40 Vortex Wakes of Flying Birds**
Geoff Spedding, University of Southern California

**4:45-5:10 Effects of Nonlinearity and Vorticity in Locomotion of Aquatic Animals**
Theodore Wu, California Institute of Technology

**5:15-5:40 Dynamics and Control of Underwater Gliders**
Naomi E. Leonard, Princeton University

**5:45-6:10 Variational Integrators for Interacting Point Vortices**
Clancy W. Rowley, Princeton University

**6:15-6:40 Efficient Navigation Routes: Utilizing the Natural Dynamics of the Ocean**
Shawn Shadden, California Institute of Technology

Saturday, May 31

# MS105

## Particle Transport in Turbulent Flows and Porous Media

*4:15 PM-7:15 PM*

*Room: Magpie A*

This minisymposium presents some recent approaches in characterizing the transport of material in flows with complex structure, such as in turbulence, geophysical flows, and porous media. The speakers will employ homogenization techniques, asymptotic stochastic analysis, novel statistical measures, and direct numerical simulations to describe how particles disperse and mix in complex flows. Gains in understanding from such research can help in developing improved parameterization schemes for modeling the effects of unresolved fluid scales on mixing and transport in atmosphere-ocean science, chemical engineering, groundwater seepage, and oil recovery applications.

**Organizer: Peter R. Kramer**
*Rensselaer Polytechnic Institute*

**4:15-4:40 Lagrangian Properties of 2D and 3D Quasigeostrophic Turbulence**
Jeffrey Weiss, University of Colorado

**4:45-5:10 Relative Dispersion in Fully Developed Turbulence**
Guido Boffetta, Universita di Torino, Italy

**5:15-5:40 Inertial Particles in a Random Field**
Andrew Stuart and *Grigorios Pavliotis*, University of Warwick, United Kingdom

**5:45-6:10 Intermittency in Passive Scalar Decay**
Dario Vincenzi, University of Genoa, Italy

**6:15-6:40 Decay of Scalar Turbulence Revisited**
Michael Chertkov, Los Alamos National Laboratory

**6:45-7:10 Homogenization of Gravity Currents in Porous Media**
Cass T. Miller and *Richard McLaughlin*, University of North Carolina, Chapel Hill; and Daniel M. Anderson, George Mason University

Saturday, May 31

# MS106

## Computations and Dynamics of Recurrent Neuronal Networks

*4:15 PM-7:15 PM*

*Room: Magpie B*

Network models of neural computations have advanced to the state where they may be utilized to guide experimental studies and to provide a framework for further, higher level,P theoretical modeling. This minisymposium will focus on the kinds of computations recurrent networks are capable of by way of models of the visual cortex, parametric working memory and oculomotor control. In these examples, the mathematical understanding of basic network functions is achieved by a combination of large-scale numerical simulations and analytic reduction using mean-field or population density methods.

**Organizer: Michael J. Shelley**
*Courant Institute of Mathematical Sciences, New York University*

**Organizer: Louis Tao**
*Courant Institute of Mathematical Sciences, New York University*

**4:15-4:40 Scale-up of Visual Cortex Modelling**
Michael J. Shelley, Courant Institute of Mathematical Sciences, New York University

**4:45-5:10 Simple and Complex Cells in a Mean-Field Model of the Visual Cortex**
*Anette Hosoi,* Massachusetts Institute of Technology; and Michael J. Shelley, Courant Institute of Mathematical Sciences, New York University

**5:15-5:40 Mexican Hats and Pinwheels in Visual Cortex**
Haim Sompolinsky, Hebrew University, Israel; *Kukjin Kang*, New York University/Center for Neural Sciences; and Michael J. Shelley, Courant Institute of Mathematical Sciences, New York University

**5:45-6:10 Working Memory in Networks of Spiking Neurons**
Nicholas Brunel, CNRS - NPSM - Universite Paris Rene Descartes, France

**6:15-6:40 Dynamics of a Recurrent Network with Synaptic Failure and Hidden Neurons**
Michael J. Shelley, Louis Tao, and *David Cai*, Courant Institute of Mathematical Sciences, New York University

**6:45-7:10 Simple and Complex Cells in Primary Visual Cortex**
Robert Shapley, New York University/ Center for Neural Sciences; and Michael J. Shelley, David W. McLaughlin, and *Louis Tao*, Courant Institute of Mathematical Sciences, New York University

Saturday, May 31

# MS107

## Applied Symbolic Dynamics

*4:15 PM-7:15 PM*

*Room: Wasatch A*

The natural language of information flow in chaos is symbolic dynamics, and establishing an effective symbolic representation for a particular system results in a fundamental understanding of its behavior. Tools to understand and tap into this are necessary to establish chaos for engineering applications. One goal of this minisymposium is to introduce new tools for learning a system's symbolic dynamics, especially robust techniques effective for measured data. Determining an accurate and useable generating partition is of great importance, as are the consequences of using an approximate or incorrect partition. A second goal is to use symbolic dynamics to analyze and improve elements of chaos engineering. Finally, the presentations will also highlight the need for continued growth in the mathematical underpinnings necessary to apply symbolic dynamics to more complex physical systems, such as those modeled by delay and partial differential equations.

**Organizer: Ned J. Corron**
*US Army AMCOM*

**4:15-4:40 Estimating Good Discrete Partitions from Observed Data: Symbolic False Nearest Neighbors**
Michael Buhl and *Matthew Kennel*, University of California, San Diego

**4:45-5:10 Symbolic Analysis of Scalar Time-Series**
Kevin Judd and *Yoshito Hirata*, University of Western Australia, Australia

**5:15-5:40 Symbolic Dynamics via Algebraic Topology**
Konstantin Mischaikow, Georgia Institute of Technology

**5:45-6:10 How Hot is Hot? Modeling, Measurement and the Role of Partition Placement**
*Erik Bollt,* Clarkson University; Ted Stanford, New Mexico State University; Ying-Cheng Lai, Arizona State University; and Karol Zyczkowsk, Center for Theoretical Physics, Polish Academy of Sciences, Poland

**6:15-6:40 Information Flow in Chaos Synchronization**
Shawn Pethel, US Army AMCOM

**6:45-7:10 A Dynamical Systems Approach to Signal Theory**
Scott Hayes, Syncrodyne Systems Corporation

Saturday, May 31

# MS108

## Modeling, Analysis and Control of Network-Based Dynamical Systems

*4:15 PM-7:15 PM*

*Room: Wasatch B*

Many complex systems share the property of being defined in terms of an underlying network. Examples include electric power generation systems, social systems and computer and communication networks as well as general agent-based approaches. The presentations in this minisymposium involve applications of dynamical systems and control theory to examples from several of these areas. The goal is to describe interesting aspects of the behavior of network systems in terms of the microscopic rules of behavior of each node and/or the large scale properties of the underlying network. Methods used include bifurcation theory, geometric control theory and system identification, as well as recent ideas from network theory.

**Organizer: Ernest Barany**
*New Mexico State University*

**4:15-4:40 Dynamical Modeling and Analysis of Electric Power Networks**
Ernest Barany, New Mexico State University

**4:45-5:10 Modeling and Analysis of Computer Networks**
Maciej Krupa, New Mexico State University

**5:15-5:40 Application of Differential Geometric Control Methods to Network Dynamical Systems**
Steve Schaffer, New Mexico Institute of Mining and Technology

**5:45-6:10 Consistent Model Hierarchies of Electric Power Networks that Preserve Local Accessibility Properties**
Ernie Barany, New Mexico State University; and *Kevin Wedeward*, New Mexico Institute of Mining and Technology

**6:15-6:40 Impact of Dynamical Generation Models on Power System Stability**
Steven Ball, ICASA New Mexico Institute of Mining and Technology

**6:45-7:10 Vulnerability Analysis of Complex Networks**
Kristin Glass, Mauro Trabatti, and *Richard Colbaugh*, New Mexico Institute of Mining and Technology

Saturday, May 31

# MS109

## Uncertainty Quantification in Dynamical Systems Theory

*4:15 PM-6:45 PM*

*Room: Superior A*

Prediction of the behavior of complex dynamical phenomena is often a goal of modeling and simulation. Increasingly, high stakes engineering projects are designed predicated on simulation results, and there are risks associated with deviation of simulation from reality. In such situations it is imperative to characterize the uncertainties in the deviation of simulation from reality, so that benefits and risks may be assessed. These uncertainties may be characterized by a variety of schemes. This minisymposium presents a sampling of such schemes, adapted to several different dynamical systems contexts.

**Organizer: Thomas J. Taylor**
*Arizona State University*

**4:15-4:40 A Stochastic Projection Method for Fluid Flow**
Habib N. Najm, Sandia National Laboratories; Omar M. Knio and Roger Ghanem, Johns Hopkins University; and *Olivier Le Maitre*, Universite d'Evry Val d'Essone, Evry, France

**4:45-5:10 Bayesian Estimation of Uncertainty in Dynamical System Modeling**
Thomas J. Taylor, Arizona State University

**5:15-5:40 Uncertainty Quantification of Large Computational Engineering Models**
Steve Wojtkiewicz, Sandia National Laboratories

**5:45-6:10 A Geometry of Stochastic Systems**
John Red-Horse, Sandia National Laboratories; and *Roger Ghanem*, Johns Hopkins University

**6:15-6:40 Error Distribution Models for Strong Shock Interactions**
John W. Grove, Los Alamos National Laboratory

Saturday, May 31

# MS110

## Vortex Dynamics and Numerical Simulations

*4:15 PM-7:15 PM*

*Room: White Pine*

Vortex dynamics is an old field that is currently seeing an explosion of new results and connections to previously unsolved problems in coding theory and numerical quadrature. Much of this recent activity focuses on statistical mechanics and monte-carlo simulations of ensembles of vortices on the plane and on the sphere. The KAM theory of vortices and applications of vortex dynamics to atmospheric sciences and vortex sheets are on-going projects in this field. This minisymposium is aimed at bringing together researchers in this exciting field involving dynamical systems, statistical mechanics and numerical simulations.

**Organizer: Chjan C. Lim**
*Rensselaer Polytechnic Institute*

**4:15-4:40 Monte-Carlo Simulations and the Physics of 2D Vorticity**
*Chjan C. Lim*, Rensselaer Polytechnic Institute; and Syed M. Assad, National University of Singapore, Republic of Singapore

**4:45-5:10 Vortex Sheet Simulations**
Robert Krasny, University of Michigan, Ann Arbor

**5:15-5:40 Theoretical and Numerical Issues Related to Vorticity and Energy Fluxes in 2D and QG Turbulence**
*Ka-Kit Tung*, University of Washington; and Wendell Orlando, Colorado Research Associates

**5:45-6:10 Periodic Motion for Coaxial Vortex Ring Configurations**
Jyoti Champanerkar and *Denis Blackmore*, New Jersey Institute of Technology; and Chengwen Wang, Rutgers University, Newark

**6:15-6:40 A Statistical Equilibrium Theory of Axisymmetric Flows with Application to the Vortex Ring Pinch-off Process**
Kamran Mohseni, University of Colorado, Boulder

**6:45-7:10 The Spherical Model of Logarithmic Potentials as Examined by Monte Carlo Methods**
Joseph Nebus, National University of Singapore

Saturday, May 31

# MS111

## Dynamical Systems and Geophysical Flows: Directions and Challenges for the Future

*4:15 PM-7:45 PM*

*Room: Ballroom I*

There has been many efforts to apply Dynamical Systems theory to geophysical flows. This session focuses on three subjects. First, advances in high-frequency radar technology, ocean modeling and data assimilation provide us with the means to study the ocean as a dynamical system. Second, we investigate the methods that can be used to study ocean processes, such as hyperbolic trajectories, Lyapunov exponents, lobe dynamics, stable/unstable hyperbolic material lines and passive tracers dynamics. Third, we highlight applications which result from applying dynamical systems to geophysics. We wish to present an overview of past research, discuss current work and develop strategies for the future.

**Organizer: Chad Coulliette**
*California Institute of Technology*

**Organizer: Francois Lekien**
*California Institute of Technology*

**4:15-4:40 Strange Eigenmodes in Diffusive Mixing**
Weijiu Liu and *George Haller*, Massachusetts Institute of Technology

**4:45-5:10 Uncertainty and Predictability in Geophysical Flows: The Role of the Koopman Operator**
Igor Mezic, University of California, Santa Barbara

**5:15-5:40 Extracting Structures Out of Closed Chaotic Flows**
Judit Schneider, Universität Potsdam, Germany

**5:45-6:10 Lagrangian Transport and its Implications for Ocean Modeling**
Christopher Jones, University of North Carolina, Chapel Hill

**6:15-6:40 ONR's program in Dynamical Systems and Ocean Modeling**
Reza Malek-Madani, Office of Naval Research

**6:45-7:10 Lagrangian Coherent Structures in High-Frequency Radar Data: Open-Boundary Modal Filtering, Hyperbolic Trajectories and Lyapunov Exponents in Monterey Bay**
Francois Lekien, California Institute of Technology

*MS 111 continued*

**7:15-7:40 A Lagrangian Stochastic Model for Dispersion in Unsteady Inhomogeneous Sub-filter Scale Turbulence**

Chad Coulliette, California Institute of Technology

## Conference Adjourns

*7:45 PM*

# Abstracts

SIAM
CONFERENCE
ON APPLICATIONS
OF DYNAMICAL
SYSTEMS

MAY 27 - 31, 2003
SNOWBIRD SKI & SUMMER RESORT
SNOWBIRD, UT

*Abstracts published as submitted by authors.*

## CP1

### Impulsively Forced Faraday Waves

We consider standing waves excited by time-periodic vertical acceleration of a fluid layer, in the case of delta function acceleration. In contrast to sinusoidal forcing there are no harmonic resonance tongues. Using a model applicable to weakly viscous deep fluid layers, we derive an amplitude equation describing onset of one-dimensional standing waves and obtain analytically the cubic Landau coefficient. We compare our results with those obtained using sinusoidal forcing and highlight important differences and similarities.

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## CP1

### Nearly Inviscid Faraday Waves in An Elliptical Container

The weakly nonlinear dynamics of nearly inviscid Faraday waves in slightly elliptical containers is considered. Because rotational symmetry is broken the surface wave amplitudes couple to an associated streaming flow, and the slow dynamics of the system must be described by a set of coupled amplitude-streaming flow (CASF) equations. In the high frequency limit the CASF equations simplify, permitting one to understand the origin of the complex dynamics generated by the interaction of the surface waves and the streaming flow. This complex behavior is related to the presence of a symmetry-breaking Hopf bifurcation that occurs only if the streaming flow is retained.

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## CP2

### Detecting Phase-Locking: Synchronization Index Vs. Coherence Function

In experimental neuroscience, the linear coherence function is commonly used as a measure of phase-locking between measurements made at different locations in the brain, or between measurements made in the brain, and from other sources. Recently nonlinear measures of phase-synchronization have been used for this purpose as well. Some controversy exists concerning whether such measures are superior to the coherence function for the detection of phase-locking. We present here some numerical and analytical results clearly demonstrating that, in general, the synchronization index, which is commonly used to measure phase-synchronization, is superior to the coherence function. We also present the conditions under which the coherence function can be expected to fail as a measure of phase-locking, and explain why the synchronization index does not. this work will be presented in the context of the analysis of synchronization processes in the brain.

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## CP2

### The Crayfish Caudal Photoreceptor Neurons: Synchronization and Frequency Doubling*

Hydrodynamic signals are detected in the crayfish peripheral nervous system by a set of hairs arrayed over the surface of the animals tailfan. These mechanosensors connect to afferent neurons that synapse onto two photoreceptor neurons (caudal photoreceptors, or CPRs). We demonstrate stochastic phase synchronization of the CPRs with weak, sinusoidal hydrodynamic signals similar to those generated by predators of the crayfish. The effects of light intensity on the synchronization and transduction processes are explored.

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## CP2

### Experimental Phase Synchronizous Chua Oscillator

Even though the extensive amount of work on the perturbed Chua oscillator, little is known about its phase synchronization process. Experimental and numerical results of phase synchronized states of the Chua circuit forced with a periodic pacing function will be presented. Interesting features of the Arnold tongues of both experimental and numerical procedures will be discussed.

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## CP3

### Self-Preservation of Most Probable Energy in Shell Model of Isotropic Turbulence

Using a shell model, we examine decaying 3D isotropic tur-

bulence. We compute large ensembles of solutions for astronomically long times at high Reynolds numbers. Individual solutions are chaotic, but ensemble averages yield power laws. The energy pdf is skewed so the mean energy differs drastically from the most probable energy. We find complete self-preservation for the most probable energy and its spectrum, but not for the (arithmetic) mean.

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### CP3

### Statistics of Levels in Turbulent Flow

Particle level set method is used to investigate the statistics of levels in two-dimensional turbulent flow. The numerical scheme will be discussed, and we first present results for passive level sets, focusing on the statistics of curvature, stretching, and patterns of levels for various mixing flows. We then compare with statistics for active levels, which affect the stirring flow through surface tension as in immiscible fluids (or multiphase flows) or in binary fluids where a free energy is associated with the geometry of the interface. We also present results for viscoelastic fluids where the viscosity stratification is essential, and investigate their effects on the mixing properties.

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### CP4

### Multi-Frequency Craick-Criminale Solutions to the Navier-Stokes Equations

The construction of multi-frequency Craik-Criminale solutions to the incompressible Navier-Stokes equations on an unbounded physical domain is discussed. It is shown that one can iteratively add Kelvin waves to any exact solution. This is illustrated by an example in which three Kelvin waves with incommesurate phases are added to a rigidly rotating column of fluid.

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### CP4

### Shear Layer Modeling Using $\alpha$-Euler Equation

We obtain the equations of motion for a vortex sheet in two dimensions from the $\alpha$-Euler equation. Vorticity is assumed to be concentrated on a curve and advected by a filtered velocity. When this curve is a single-valued function of the stream-wise coordinate, these equations have a particularly simple representation as a system of PDE's in one spatial variable and time. We study the structural properties of this system such as its response to perturbations of various types and also its behavior during roll-up and vortex merger. We explore control strategies, focussing on actuation through manipulation at the point of creation of the vortex sheet.

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### CP4

### Periodic Vortex Motion on a Sphere

Equilibrium configurations of point particles correspond to different extremal states leading to polyhedral solutions in classical optimization problems like distributing N point charges on a sphere. Our focus will be on logarithmic interactions, hence the particles are point vortices and the solutions represent interesting equilibria and periodic discretizations of the Euler equations. Focus will be on configurations obtained from Platonic and Archimedean solids, as also vortex buckyballs which lead to stable periodic orbits evidenced by their Floquet spectrum.

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### CP5

### Predator-Prey Dynamics with Disease in the Prey

The Holling-Tanner model for predator-prey systems incorporating an SI (susceptible, infected) model for the spread of disease in the prey is considered. The bifurcation diagram is discussed from the viewpoint of how parameters proportional to the disease transmission rate and maximum predator consumption rate affect the dynamics. The assumption that the diseased prey are easy to capture allows for the use of two-timing to describe the underlying bifurcation mechanisms.

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### CP5

### Front Propagation and Segregation in a Reaction-Diffusion Model with Cross-Diffusion

We study front propagation and segregation in a reaction-diffusion system with cross-diffusion describing competing biological species with self- and cross-population pressure. Depending on the stability of the fixed points, fronts are uniform or have spatial structure. In the latter case, a cross-diffusion instability leads to segregation in the wake of the front. The segregated state consists of layered structures. A Ginzburg-Landau amplitude equation is used to describe the dynamics near marginal stability [del-Castillo-Negrete, et al., Physica D, 168-169, 45 (2002)].

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## CP5

### Higher Codimension Bifurcations in Ecosystem Models

The bifurcation structure of ecological models is particularly interesting because of the strong nonlinearities that arise in species interaction. We discuss how higher codimension bifurcations arise in different realistic ecosystem models. The bifurcations are shown to cause unexpected or paradoxical behaviour of the system. We present several unusual but realistic scenarios leading to the extinction of species. Our results are illustrated by three-parameter bifurcation diagrams that have been obtained analytically from a general foodchain model.

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## CP6

### Parameter Space Reconstruction from Experimental Time Series

Using time series measured for different parameter values of an experimental system one can reconstruct its parameter dependence and bifurcation diagrams. Depending on features of the dynamical system and the observation different methods for modelling may be employed. An important prerequisite for accurate results is the robustness and generalization capability of the model. This goal is achieved by making use of ensemble regression methods. Numerical and experimental results are presented.

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## CP6

### Multiple Modeling Analysis of Chaotic Systems

The main goal of this work is to make a multiple regional modeling analysis of reconstructed attractors starting from time series. With a criterium of depending on density of points we select subsets of the total attractor. Then we obtain regional dynamical systems of ordinary differential equations. Each systems has different topological properties. We explore the possibility of obtaining the global dynamical systems as a weighted average of the regional models.

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## CP6

### Approximating Stable and Unstable Manifolds in Experiments

We introduce a novel procedure to reveal invariant stable and unstable manifolds given only experimental data. We assume a model is not available and show how coordinate delay-embedding applied to invariant phase space regions can be used to construct stable and unstable manifolds of an embedded saddle. The method is able to capture the fine structure of the manifold, is independent of dimension, and is efficient relative to previous techniques.

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## CP7

### Towards Topological Analysis of Higher-Dimensional Chaos

Topological analysis is a powerful approach for characterizing low-dimensional chaotic behavior. It proceeds by extracting information about stretching and squeezing from the knot invariants of unstable periodic orbits, which makes it currently unsuitable for analyzing attractors of dimension greater than three. However, knots are only a tool: the foundations of the topological approach survive in higher dimensions. We discuss how to develop a knotless topological analysis so that it can be extended to higher-dimensional systems.

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## CP7

### Knotted Invariant Manifolds in a System with QP Forcing

We examine a damped, quasiperiodic Mathieu equation with cubic nonlinearities. We find that the attracting set for the Poincaré map is an invariant manifold in the form of a knot or link. A sequence of bifurcations occurs through which the topological structure of the manifold is changed. After sufficiently many bifurcations, the knot structure dissolves, leaving a fractal attractor. Finally, we consider the knottedness of the attracting 2-torus in the full phase space.

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## CP7

### Fourth Order Differential Equations Via Braids

We consider fourth order differential equations with a variational structure. For a broad class of such *fourth* order equations, the problem of finding periodic solutions can be reformulated in terms of *second* order recurrence relations, i.e., a lattice with nearest neighbour coupling. Choosing appropriate lattice dynamics, the Conley index can be used

to find critical points, corresponding to periodic patterns, of many topologically distinct braid types.

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## CP8

### Action and Period of Homoclinic and Periodic Orbits for the Unfolding of a Saddle-Center Bifurcation

The saddle-center bifurcation is dynamically unfolded due to a slowly varying potential. Asymptotic expansions for the action, period, and dissipation are obtained in an overlap region near the homoclinic orbit of the saddle-center bifurcation. In addition, the unfoldings of the action and dissipation functions associated with zero energy orbits (periodic and homoclinic) near the saddle-center bifurcation are determined using the method of matched asymptotic expansions for integrals.

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## CP8

### Homoclinic and Heteroclinic Connections in Perturbed Hamiltonian Systems with Saddle-Centers

We study three or more degrees of freedom perturbed Hamiltonian systems such that the unperturbed systems have an invariant plane on which there is a homoclinic orbit to a saddle-center. We develop a Melnikov-type technique for analyzing the persistence of homoclinic and heteroclinic connections between invariant tori near the unperturbed saddle-centers, and creation of them by the perturbations and higher-order terms.

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## CP8

### Implicit Dynamical Systems: Solvability, Asymptotics, Number of Solutions

I describe a new approach which enables one to solve both regular and singular initial value problems. Implicit ODE's and FDE's are under consideration. Existence of continuously differentiable solutions in the neighborhood of the initial point is being proved. Asymptotic behaviour of these solutions is being plotted. The number of such solutions is being determinated. I find new effective asymptotics for solutions.

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## CP9

### Resonance and Capture of Sine-Gordon Solitons

We study the interaction of traveling waves with a delta-well defect for $u_{tt} - u_{xx} + \sin u = \epsilon\delta(x)\sin u$. When $\epsilon = 0$, the system is well-known to have "kink" solitons. For $\epsilon > 0$, the solitons may interact with the defect in a manner depending on their speed. Above a critical velocity $v_c$, the kinks pass by the defect, losing speed. Below $v_c$, they may be captured or reflected depending on $v_c$. Fei et.al. derived a model ODE for this system and gave an empirical explanation of this phenomenon. Using the same ODE, we derive an asymptotic formula for $v_c(\epsilon)$ and give further quantitative explanations for observed behavior.

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## CP9

### 2D-Spatial Dissipative Solitons Induced by a Saturable Absorber in Quadratic Media

Spatial dissipative solitons have been generated by introducing a saturable absorber in an optical resonator with a quadratic medium. We show that, in the context of frequency degenerate optical parametric oscillators, the saturable absorber is able to inhibit the formation of patterns, via a frequency polling phenomenon. As a consequence spatial propagating dissipative solitons are generated. These dynamical solitons have a constant transverse velocity and are stable in a large domain of parameters.

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## CP9

### Interaction of Localized Structutures in the Swift-Hohenberg Equation

The Swift-Hohenberg equation has been derived for many spatially extended systems including, chemistry, fluid mechanics, biology and optics. We consider the interaction between two separated localized structures in the regime where the pattern forming process takes place. We show that the interaction potential between two localized structures can be derived explicitly in terms of the modified Bessel function describing the asymptotic behavior of the localized structure tail.

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## CP10

### Correspondence Between the Difference Equations and Differential Equations for Global Modeling

In 1981 Takens [F. Takens, *Lecture Notes in Mathematics*, 898, p. 366, 1981] showed how a single time series can be used to construct a geometrical object, an embedding in a space spanned by the time series and its successive derivatives that is topologically and diffeomorphically equivalent to the underlying dynamical system. Based on this, a model of the generating dynamics in terms of ordinary differential equations (ODEs) can be reconstructed directly from a time series. Recently Tempkins and Yorke [J. Tempkin and J. Yorke, *Journal of Difference Equations and Applications* 8(1), p. 13, 2002] proposed a new theorem for the existence of a set of difference equations reproducing the delay embedding. The correspondence between the difference and the differential models, however, remains unsolved. Here we consider the analytical description of an embedding which we obtain using a recently derived Ansatz Library method [C. Lainscsek, C. Letellier, and F. Schürrer, *Physical Review E*, 64, p. 016206, 2001]. The Ansatz Library method a fundamentally different approach from the conventional theory because it is based on the dynamical properties of the underlying system rather than on the geometrical properties. This method allows us to obtain differential models which contain no spurious terms, from single noise-free time series. We then show how to translate the differential equations into difference equations using Taylor series expansions of the derivative coordinates. We show that when the difference equations are iterated, they preserve the topological properties of the embedding. These equations represent the first theoretically obtained limit of numerically derived NARMAX (Non-linear Auto-Regressive Moving Average model with eXogenous inputs) models [L. Aguirre and S. Billings, *Int. J. Bifurcations & Chaos*, 5, p. 449, 1994] as we show on the example of the $y$-coordinate of the Rssler system. This work is a first important step toward understanding an existence of possible equivalence between delay and derivative embedding.

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## CP10

### Semi-Discretization of Time-Periodic Delay-Differential Equations

A special kind of discretization technique is applied with respect to the time delay in linear periodic DDEs. This leads to an efficient method for their stability analysis. Stability charts are presented for the delayed Mathieu equation of the form

$$\ddot{x}(t) + (\delta + \epsilon\cos(4\pi t))x(t) = c\int_{-1}^{0} w(\vartheta)x(t+\vartheta)d\vartheta$$

with different weight functions $w$ occurring in mathematical models of high-speed milling.

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## CP10

### Nonlinear Oscillations in Microvascular Blood Flow

We consider the dynamics of blood flow in microvascular networks, including the Fahraeus Lindqvist effect and plasma skimming. While previous numerical studies have suggested that spontaneous oscillations are possible in large networks, the simplest topology that permits oscillations was not identified, nor the relevant parameter regime. We demonstrate that oscillations are possible in the simplest possible network - a 2-node model. Our analysis is based on transforming the governing convection equations into a delay differential model with multiple state-dependent delays. A linear stability analysis reveals the existence of a Hopf bifurcation, and explicit restrictions on the parameters are obtained. These results are confirmed by direct numerical simulation.

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## CP11

### On the Stability of Pulses in Nonlinear Schrödinger Equations

Nonlinearly coupled Schrödinger equations serve as models for a variety of optical phenomena — and these equations support many novel pulses. Reformulating the eigenvalue problem as a shooting problem in a Grassmannian manifold, we derive a topological criterion for the stability of such pulses. This provides a clear geometric mechanism spurring pulse instability as a parameter changes and even allows us to find a new family of stable bifurcating pulses.

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## CP11

### A Priori Stable, a Priori Unstable and Bifurcating Systems, Frequency Maps and Instabilities

A geometrical study of Hamiltonian systems with $n \geq 3$ d.o.f. is conducted, enabling to identify potential instabilities in the near integrable system. Plots of unperturbed energy surfaces in the frequency space and their connection to the corresponding energy-momentum bifurcation diagrams demonstrate the difference between a priori stable, a priori

unstable and bifurcating systems. The connection between certain instabilities in the latter, secondary resonances and the structure of the unperturbed energy surfaces in the frequency space is shown.

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## CP11

### Controllability of N-Degree of Freedom Integrable Hamiltonian Systems

We study the controllability of n degree of freedom integrable Hamiltonian system with bounded time-dependent non-dissipative control perturbation. We give necessary and sufficient condition for the global controllability of these systems. In contrast to the time independent perturbation case of Kolmogrov-Arnold-Moser theorem, no invariant structure survives if the perturbation is made function of time. The result is contrasted with standard methods of showing controllability for nonlinear systems.

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## CP12

### Dynamics of a Quasigeostrophic Ellipsoidal Vortex Moment Model

Stably stratified atmospheres and oceans are well-approximated by the 3D quasigeostrophic equations. Numerical simulations show that the fluid is populated by nearly ellipsoidal, moderate aspect-ratio coherent vortices. The ellipsoidal moment model provides a Hamiltonian description of these vortices. For two vortices, after reduction, the moment model has an eight dimensional phase space. We investigate the dynamics of this system, focusing on the physically important processes of vortex merger and vertical alignment.

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## CP12

### Stably-Stratified and Unstably-Stratified Quasi-geostrophic Flows

Numerical simulations of rotationally constrained flows are unable to reach geophyscially realistic parameter values, e.g., Reynolds *Re* and Richardson *Ri* numbers. In particular, low values of the Rossby number *Ro* and *Ri* compound the already prohibitive temporal and spatial restrictions present for high-*Re* simulations by engendering high frequency inertial waves and the development of thin (Ekman) boundary layers. Recent work in the development of reduced partial differential equations (pde's) that filter fast waves and relax the need to resolve boundary layers has been extended to construct a hierarchy of reduced pde's that span the stably- and unstably-stratified limits. By varying the aspect ratio for spatial anisotropy characterizing horizontal and vertical scales, rapidly rotating convection and stably-stratified quasi-geostrophic motions can be described within the same framework. Furthermore, these regimes can be coupled via a multiple scales analysis. Solutions will be presented for the convective limit in the $f$-plane approximation with the aid of a simple, non-orthogonal coordinate transformation.

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## CP13

### Optimizing the Earth to Mars Trajectory

The interplanetary trajectory from Earth to Mars is difficult to solve numerically. Typically a problem with four or more unknowns requires a genetic algorithm to solve, the problem being intractable to any other nonlinear optimization methods. This paper shows how an Earth to Mars trajectory with twenty five unknowns can be solved directly, without the use of any nonlinear optimization methods whatsoever. The basic method finds a trajectory which is either thirty days faster than the nominal Hohmann Transfer (i.e. using the same total thrust as a Hohmann), or a trajectory which has the same time of flight as the Hohmann but uses 10% less total thrust. Simple variations to this model lead to even better results, but are not in the scope of this report. This report is intended to show how the optimization algorithm is constructed and how it arrives at a fast, efficient solution.

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## CP13

### Chaotic Orbits in a Perturbed Sitnikov Problem

We consider a spatial four-body system consisting of a heavy body, a binary moving in a nearly circular orbit about the heavy body, and a massless particle moving near the binary. It is assumed that the motion of the binary occurs near a moving plane perpendicular to the plane of the nearly circular orbit about the heavy body. It is also assumed that the initial position of the massless particle relative to the binary is as in the Sitnikov problem

[Mo]. Orbit simulations indicate that the massless particle makes chaotic excursions between the orbits of the binary. The chaotic transitions occur through dynamical channels [KLMR]. The presence of these dynamical channels suggests the existence of stable and unstable manifolds and of symbolic dynamics. We present numerical simulations as well as a model for this problem, in which the Sitnikov configuration is subject to periodic/quasiperiodic perturbations. References: [KLMR] W.S. Koon, M.W. Lo, J.E. Marsden and S.D. Ross, Heteroclinic connections between periodic orbits and resonance transitions in celestial mechanics, Chaos 10(2), 2000, 427-469. [Mo] J. Moser, Stable and Random Motions of Dynamical Systems, Princeton University Press, 1973.

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### CP13

### Relative Equilibria and Saari's Conjecture

A periodic solution to a Hamiltonian system which reduces to an equilibrium point under a particular symmetry group is called a *relative equilibrium.* These are particularly important solutions in the $n$-body problem, where the $n$ bodies form a *central configuration* which rigidly rotates about its center of mass. Such a solution has a constant moment of inertia, a fixed "size". Saari conjectured that the only possible solutions with a fixed moment of inertia are in fact relative equilibria. We explore this question in the $n$-body problem as well as for other Hamiltonian systems showing that the conjecture fails for certain types of physical systems.

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### CP14

### Continuation of Invariant Subspaces for Large and Sparse Bifurcations Problems.

The Continuation of Invariant Subspaces (CIS) algorithm [Demmel, Dieci, Friedman 2001] and [Dieci, Friedman 2000], produces a smoothly varying basis for an invariant subspace R(s) of a parameter dependent matrix A(s). We consider the situation when the continued spectral set, associated with R(s), corresponds to few eigenvalues of A(s) near the imaginary axis and contains all information about potential bifurcations. We develop reliable procedures for updating R(s) when eigenvalues are added and/or removed from the continued spectral set. We extend the CIS algorithm to the case of large sparse matrices using projection methods. We consider several examples, including stability analysis of a simulation model of the single stage to orbit reusable launch vehicle called the X-33.

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### CP14

### Bifurcations in a Differentially Heated Rotating Spherical Shell

We study the steady axisymmetric bifurcations that occur in a model that uses the Navier-Stokes equations in the Boussinesq approximation to describe the fluid flow in a differentially heated rotating spherical shell with radial gravity (i.e., a model for large-scale atmospheric dynamics). The solutions and the corresponding eigenvalues are approximated numerically from the large sparse systems that result from the discretization of the partial differential model equations.

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### CP14

### Numerical Bifurcation Analysis of Lattice-Boltzmann Models

We will compare the "equation-free" approach advocated by Prof. I.G. Kevrekidis and coworkers (invited speaker) to a traditional bifurcation analysis for the FitzHugh-Nagumo model given by a lattice-Boltzmann model and by a partial differential equation. Our tool for this is the Newton-Picard method, a matrix-free method equally suited for numerical bifurcation analysis of maps and timestepper-based bifurcation analysis. We will also outline some pitfalls in this approach.

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### CP15

### Trapping in a Magnetic Field with Reversed Shear

A negative magnetic shear configuration reduces particle transport in tokamaks. We introduce an analytically derived non-twist map to study the reconnection, bifurcation, and transport barrier created by dimerized magnetic islands. In this work, the resonant perturbations are created by a magnetic limiter. The barrier is interpreted in terms of an invariant chaotic set.

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### CP15

### From Many-Body Hamiltonian Dynamics to Kinetic Equations in Weak Plasma Turbulence

Quasilinear equations describe e.g. weak warm beam-plasma instability saturation. We prove them in the (debated) strongly nonlinear chaotic regime without 'random phase approximation'. Describing the wave-beam system as a finite-dimensional Hamiltonian system, we use that *(i)* any particle motion and wave evolution affect weakly each other, and *(ii)* chaotic dynamics regenerates stochasticity of phases ('molecular chaos') quickly enough.
[Y. Elskens and D. Escande, *Microscopic dynamics of plasmas and chaos* (IoP Publishing, Bristol, 2002).]

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### CP15

### Action Principle Derivation of Reduced Magneto-Fluid Models

It is well-known that ideal MHD possesses an action principle formulation when it is expressed in terms of Lagrangian (or material) variables, and similar action principles exist for magnetofluid models that include more general equations of state (CGL) or more sophisticated means for momentum transport (gyroviscosity). We show how to begin from these action principles and derive reduced Hamiltonian models such as reduced MHD and other reduced fluid models.

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### CP16

### Disorder in Ginzburg-Landau Systems and the Statistics of Defect Dynamics

The break-down of order in patterns is often associated with defects. In the complex Ginzburg-Landau equation (CGL) and the $xy$-model the defects are zeroes of the complex order-parameter field. Their trajectories form loops in space-time. We simulate the CGL in the defect-chaotic regime and find that various distribution functions for the loops exhibit parameter-independent power laws. We apply the loop statistics to study the $xy$-model near the defect-unbinding Kosterlitz-Thouless transition.

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### CP16

### Anlytical Studies of the Interaction Between Turing Instabilities in Semiconductors Cavities

The interaction of two Turing instabilities in a coherently driven semiconductor cavity is investigated. An amplitude equation is derived in the limit where the two instabilities are close to another. An infinity of branches of periodic solutions are found to emerge from the unstable portion of the homogeneous branch. These branches have a non-trivial envelope in the bifurcation diagram that can either smoothly join the two instability points or form an isolated branch of solutions.

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### CP16

### Slipping Sticks: Micromechanics of Vortex Formation in a Vibrated Layer of Granular Rods

Recently, Neicu, Kudrolli et al. observed that a system of vibrated rods spontaneously formed the long-range orientational order. Above the critical packing fraction the cooperative motion of rods resulted in a formation of vortex structures. We present a detailed microscopic model complemented by 3D molecular dynamics simulations which extends the phenomenological description proposed by Tsimring and Aranson. First, we consider the mechanics of in-plane, eccentric, oblique collision between the rod and vibrating plate. We construct a 2D map which relates post-collisional velocities of a rod for two successive impacts on the plate. The map possesses a fixed point which describes the average drift velocity of a row of tilted rods as a function of the mean tilt, motion of the plate, and micromechanical characteristics of the collision. This simple solution quantitatively agrees with the quasi-2D experiment with "dancing pens" and qualitatively explains the properties of the vortices observed experimentally. Next we implement an effective 3D MD algorithm which allowed us to verify our theoretical results and study the dynamics of the vortex formation.

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### CP17

### Statistical Considerations In The Estimation and Testing of Dynamic Biological Models in Experi-

**mental Settings**

Many seemingly random biological system processes can be expressed in terms of simple nonlinear dynamic functions. These may be based upon population dynamics or other aspects of biological systems evolving through time. In experimental settings, such mathematical representations can yield likelihood functions that are unstable. The cause of some instabilities is discussed and whether the resulting likelihoods can be reasonably smoothed without undue loss of information. If smoothing is not feasible, randomization based testing is discussed.

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## CP17

## Synchronization-Based Parameter Estimation

Consider a chaotic, dynamical system that may be modeled by a parameter-dependent, deterministic map. A synchronization-based method is presented whereby the time-series generated by a scalar observable may be utilized to determine the model parameters. In this method, rather than using just the overall synchronization quality for a given set of trial parameter values, the synchronization adjustments at every iterate are used. This leads to some interesting advantages. Supporting numerical results are presented.

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## CP17

## Global Model As a Sum of Regional Models from Time Series

We consider the problem of modeling chaotic systems starting from time series data. The reconstructed attractor is divided in two qualitative different regions with the purpose of exploring their different topological characteristics and relate them to the nonlinearities of the dynamical system. For each region a dynamical systems is obtained. So that the total dynamical system is represented by a "sum" ($\oplus$) of regional dynamical systems. The Lorenz and Rossler systems are studied.

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## CP18

## Parametric Resonance in Spatially Distributed Systems

We consider spatially distributed systems described by Partial Differential Equations (PDEs) in which some of the coefficients are spatially periodic functions. Such systems arise in certain distributed sensorless control schemes which are analogous to so-called vibrational control. We show how the mechanism by which certain sensorless periodic feedbacks stabilize or destabilize systems is related to similar mechanisms known in parametric resonance. We develop a spatio-temporal lifting framework using which we analyze stability and system norms of PDEs with periodic coefficients. Examples of PDEs in which parametric resonance occurs and their treatment with the lifting framework are given.

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## CP18

## Numerical Study of Double-Diffusive Free Convective Flow Past a Moving Vertical Cylinder

The double-diffusive free convective flow past a moving semi-infinite vertical cylinder has been studied numerically. The mass, momentum, energy and species concentration equations have been solved by a finite difference method using an implicit scheme of Crank-Nicolson type. The finite difference scheme is unconditionally stable and accurate. Graphical results for the velocity, temperature, concentration, local and average skin-friction, Nusselt number and Sherwood number are illustrated and discussed for various physical parametric values. The role of temperature stratification in the ambient medium has been analysed.

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## CP18

## Longwave Marangoni Convection under Heterogenous Heating

Marangoni convection in a fluid layer with deformable free surface driven by spot-like heating from below is considered. The weakly nonlinear theory is developed in the longwave limit for the case of weak nonuniformity of the heating. The system of coupled amplitude equations governing the evolution of the temperature field, vorticity, and deformation of the interface is derived. The stability of the conductive, quiescent state with the planar interface is investigated in the space of parameters describing the heat flux, size of the spot, surface tension, and gravity.

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## CP19

## A Spatial/Temporal Landscape Paradigm for Epi-

**demic Simulation**

We discuss how to reduce large scale epidemic simulations, such as EPISIMS, to smaller (contracted) spatial and temporal networks. These reduced models are based on: 1) Identifying small community structures such as households, buildings, etc., within the large network, 2) Cycles starting and ending at households, where the cycle passes through the interior of a graph that denotes the spatial location of buildings and 3) Determining the connectivity of households at the end of the work day. For each time cycle, we construct two spatial models: $N$-partite and small network graphs. As time evolves, the graphs are updated and the resulting sequence of graphs produces an evolutionary structure.

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### CP19

### Lyapunov Functions for Compartmental Epidemic Models

Lyapunov functions for classic three- and four-compartment epidemic models, including those with vertical and horizontal (bilinear and non-linear) transmission, are introduced. Global properties of the models are thereby established.

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### CP19

### Self-Sustained Activity in a Network of Excitable Neurons with Local and Global Connectivity

We study the propagation of activity in a one-dimensional network of excitatory, integrate-and-fire neurons. With purely local coupling, stimulation of neurons in a subthreshold state leads to traveling solitary pusles which eventually leave the system or anihilate. We show that the addition of long-range synaptic connections can lead to a state of persistent, low-level activity in which the anihilation and creation of pulses exist in equilibrium. Furthermore, the reliability of self-sustained activity depends on the density of connections.

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### CP20

### Rings of Oscillators with Delayed Coupling

We consider a ring of oscillators linked with nonlinear, time delayed coupling. For the case of identical oscillators, we give conditions for synchronisation and desynchronisation. We show that mode interaction can lead to the coexistence of different stable oscillation patterns, or of an oscillation and a stable nontrivial equilibria.

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### CP20

### Synchronization Stability and Patterns in Scale-Free Networks of Oscillators

Networks which are smallworld systems of oscillators can have enhanced stability of the synchronous state. Many natural systems are connected in a scale-free network configuration, which has a different topology from the smallworld. Examples are the Internet, neurons, sociological systems, and cell-protein interactions. I show a generic approach to synchronization stability can be applied to scale-free networks of oscillators revealing how the synchronization stability varies with connectivity, network diameter and degree distribution.

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### CP20

### Synchronization and Total Phase Locking of Mutually Coupled Oscillators

In this lecture synchronization in fully interconnected systems of stable limit cycle oscillators is investigated. According to the Kuramoto model, the limit cycle oscillators are represented by phase oscillators, fully determined by their natural frequencies. We concentrate on stability results for populations with a finite number of oscillators. For identical oscillators we show that synchronization is globally asymptotically stable. Total phase locking is locally stable for non-identical oscillators when the coupling strength exceeds some threshold.

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### CP21

### Extensive and Non-Extensive Spatiotemporal Chaos in a Laser

A modulated multimode laser (a spatiotemporal parametric system) is a generic pattern forming system in optics. We show numerically and experimentally that different types of spatiotemporal chaos (extensive or non-extensive) occur in this system. We have evidence that these regimes stem from either a cascade of parametric process, or the spatial non uniformities always present in this system or the interaction between two patterns.

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## CP21

### Pulse Dynamics in a Laser with Delayed Feedback

We consider a laser with saturable absorber operating in the pulsating regime that is subject to delayed optical feedback. The delay feedback causes the laser pulse period to lock to an integer fraction of the feedback time. We derive a map from the original model to describe the periodic pulsations of the laser. Equations for the period of the laser predict the occurrence of the different locking states as well as the value of the pump when there is a switch between the locked states.

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## CP22

### Oscillatory Neural Model of Cognitive Functions: Feature Representation and Binding, Selective Attention, Memorisation and Novelty Detection

The model works with visual information, consists of interactive modules, which are associated with different stages of information processing, and is based on experimental evidence. The main principles of functioning include phase-locking coding, adaptation of natural frequencies, resonant response, and synchronisation. Attention is automatically directed to one object allowing the memorisation of this object in the working memory. Novelty detection is implemented as a tonic or phasic reaction to the object in attention focus.

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## CP22

### Mesoscopic Neurodynamics: The Transition To A New Equilibrium

The initial response by a sensory system to an abrupt change in stimulus can convey important information. This response can be affected by biophysical properties of a neuron as well as by prior activity. Using a population density framework, we look at the the role of various biophysical properties of a neuron in the population response to stimulus transients including the time to transition to a new steady state and the filtering of transient oscillations.

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## CP22

### Bifurcation Analysis of Amplification and Tuning Mechanisms of Auditory Hair Cells

Hair cells are frequency selective cells responsible for translating sound-induced motion into electrical signals. In amphibian hair cells there are two separate mechanisms, each poised just below a Hopf bifurcation, that contribute to the cells' frequency selectivity. We will consider a reduced model derived from physiological models of each mechanism and discuss the effects of both the unidirectional coupling between the mechanisms and their proximity to a Hopf bifurcation on amplification and tuning.

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## CP23

### Extraction of Wave Structure from Biological Data

Waves, which are signals transmitted from one part of a medium to another with a recognizable velocity, are thought to represent information transfer between units. We explore the idea of the wave as a carrier of information and use derivative relationships to perform an approximate separation of the carrier from the underlying information. We then apply this separation technique to data from in vivo, in vitro and numerical experiments on the turtle visual cortex.

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## CP23

### Dynamical Systems Analysis of Propagating Waves in Turtle Visual Cortex

Visual stimuli evoke propagating cortical waves in turtles. Information is encoded in the wave's spatiotemporal dynamics in both experiments and simulations. The dimensionality of the system can be reduced using Karhunen-Loeve decomposition and representing the wave by a trajectory in phase space spanned by the low-order coefficients. Data visualization methods are used to relate the properties of the trajectories to underlying cortical state variables, allowing the biological underpinnings of the waves to be understood.

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### CP23

### Topographic Organization of Hebbian Neural Connections by Synchronous Wave Activity

Experimental studies have revealed that the refinement of early, imprecise connections in the developing visual system involves electrical activity in the retina before the onset of vision. We study the evolution of initially random unidirectional connections between two excitable layers of FitzHugh-Nagumo neurons with simulated spontaneous activity in the input layer. Lateral coupling within the layers yields synchronous neural wave activity that serves as a template for the Hebbian learning process, which establishes topographically precise interlayer connections.

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### CP24

### A Kinetic Model of Oscillating Heterogeneous Catalytic Reaction with a Strange Attractor

We will discuss the phenomenon of weakly stable dynamics of the reaction rate in 3D model of catalytic hydrogen oxidation with fast, intermediate and slow variables and present results concerning Smale's problem: "Is a given dynamical system chaotic?" Numerical observations indicate that subharmonic cascades occur in the system while control parameters vary and there exists an attractor with an infinite number of unstable periodic orbits. We represent numerical evidence of the existence of the strange attractor which involves the identification of a transversal homoclinic orbit and a Smale horseshoe. Thus, the results imply that the typical trajectories on the attractor will be asymptotically chaotic.

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### CP24

### An Asymptotic Stability Analysis of Static Spike Autosolitons in the One-Dimensional Gray-Scott Model

We present the results of an asymptotic study of the static spike autosolitons in the one-dimensional Gray-Scott model. In the asymptotic limit, the stability problem reduces to a nonlocal eigenvalue problem. We use a direct method of assesing stability of the stationary solutions by locating the zeros of the function $D(\omega)$ in the complex plane, which determine the eigenvalues of the nonlocal problem. In the considered problem, this function can be calculated explicitly, allowing a rigorous analysis of the spectrum of the nonlocal eigenvalue problem. This analysis predicts: stability of the static spike autosolitons up to the point of the saddle-node bifurcation signifying the disappearance of solution, a Hopf bifurcation to a pulsating autosoliton, and a pitchfork bifurcation with respect to the onset of traveling motion.

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### CP24

### Stochastic Modelling and Deterministic Limit of Catalytic Surface Processes

Three levels of modelling, the microscopic, the mesoscopic and the macroscopic level are discussed for the CO oxidation on low-index platinum single crystal surfaces. The introduced models on the microscopic and mesoscopic level are stochastic while the deterministic model on the macroscopic level (reaction-diffusion equations) can be derived rigorously for low pressures as limit of the stochastic many particle model for large particle numbers. For intermediate pressures, experimentally observed noise-induced pattern formation can be reproduced.

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### CP25

### Qualitative Properties of Dynamical Problems for Nonlinear Electromagnetoelasticity System

There are considered the Cauchy and initial boundary-value problems for a nonlinear model describing the process of coupling of electromagnetic and elastic waves. We start by introducing a simple model consisting from two differential equations, one of them is hyperbolic equation (analog of Lamé system) and another one is parabolic equation (analog of diffusion Maxwell's system) coupled by nonlinear terms in both sides. There were obtained a priori estimates and existence and uniqueness theorems of solvability of corresponding problems. An application of these results can be found in explanation of nonlinear processes in the

theory of electromagnetoelastic interactions in continuum physics and geophysics.

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### CP25

### An Integrable Hierarchy and Its Parametric Solution

This talk gives an integrable hierarchy of nonlinear evolution equations. In this hierarchy there are the following representative integrable equations:

$$u_t = \partial_x^5 u^{-\frac{2}{3}},$$
$$u_t = \partial_x^5 \frac{(u^{-\frac{1}{3}})_{xx} - 2(u^{-\frac{1}{6}})_x^2}{u},$$
$$u_{xxt} + 3u_{xx}u_x + u_{xxx}u = 0.$$

The whole hierarchy is shown to be integrable through solving a key $3 \times 3$ matrix equation. The $3 \times 3$ Lax pairs and their adjoint representations are "nonlinearized" into two Liouville-integrable canonical Hamiltonian systems. Based on the integrability of $6N$-dimensional systems we give the parametric solution of the positive order hierarchy. In particular, we obtain the parametric solution of the equation $u_t = \partial_x^5 u^{-\frac{2}{3}}$. Moreover, we give the traveling wave solution (TWS) of the above three equations. The TWSs of the first two equations have singularities, but the TWS of the 3rd one is continuous. For the 5th-order equation, its parametric solution can not include its singular TWS. We also analyse the Gaussian initial solutions for the equations $u_t = \partial_x^5 u^{-\frac{2}{3}}$, and $u_{xxt} + 3u_{xx}u_x + u_{xxx}u = 0$. One is stable, the other not. Finally, we extend the equation $u_t = \partial_x^5 u^{-\frac{2}{3}}$ to a large class of equations $u_t = \partial_x^l u^{-m/n}$, $l \geq 1$, $n \neq 0$, $m, n \in Z$, which still have the singular traveling wave solutions.

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### CP25

### Geometric Invariants of Multi-Dimensional Linear Wave Conversion

In a non-uniform medium, two waves with distinct polarization and dispersion characteristics can undergo localized resonant energy transfer. Solution of the local two-component linear wave equation requires use of both congruence transformations among wave-field components, and linear canonical transformations on ray phase space. Only quantities invariant under both transformation groups have physical significance. We show that the only such invariant is the intrinsic helicity of rays as they pass through the conversion region.

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### CP26

### Recurrence Plots and Unstable Periodic Orbits

Chaotic attractors contain an infinity of unstable periodic orbits. These orbits are interesting not only because they represent an element of order within chaos, but also because they make up the skeleton of the attractor, and in an easily formalized way. An orbit on a chaotic attractor, in particular, is the closure of the set of unstable periodic orbits, and that set is a dynamical invariant. Their instability, however, makes them hard to find, and algorithms that do so are computationally complex. We propose that the recurrence plot, a two-dimensional visualization technique for sequential data, is an useful and relatively inexpensive way to get around this problem. Moreover, thinking about unstable periodic orbits is a good way to understand the rich geometric structure that appears on recurrence plots of chaotic systems. These observations suggest not only a simple way to locate unstable periodic orbits in chaotic time-series data, but also a potentially effective way to use a recurrence plot to identify a dynamical system.

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### CP26

### Homoclinic Orbits in a Piecewise System and Its Relations with Invariant Sets

In this paper we present a general numerical method to demonstrate the existence of homoclic and heteroclinic orbits in piecewise-linear systems. We also show that the tangency of the stable and unstable manifolds, at the onset of the chaotic double scroll attractor, changes the behavior basin boundaries of the infinity attractors for backward time integration. This can be used as an evidence of homoclinicity in the dynamical system.

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### CP27

### Non-Renewal Spike Trains Generated by Stochastic Neuron Models

Recently, much experimental evidence has been accumulated that correlations in the interspike interval sequences of neurons may significantly influence their signal detection and information transmission capabilities. We discuss two possible sources of such correlations: (1) a noise input with finite correlation time (colored noise) (2) a dynamical threshold. For both cases, novel analytical results for integrate-and-fire type models are given including interspike interval histograms, serial correlation coefficient, and power spectrum. We discuss the mechanisms by which (A)

negative correlations cause an enhancement in signal transmission and (B) long-range correlated noise sets a time scale of optimal signal detection.

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### CP27

### Simple Neural Architectures Generating Complex Syllables in Birdsong

We present a model for the activities of neural circuits in a nucleus found in the brains of songbirds: the robust nucleus of the archistriatum (RA). This is a fore brain song control nucleus responsible for the phasic and precise neural signals driving vocal and respiratory motor neurons during singing. Driving a physical model of the avian vocal organ with the signals generated by the neural model, we produce synthetic songs. This allows us to show that certain connectivity architectures in the RA give rise to a wide range of different vocalizations under simple excitatory instructions. Examples are discussed.

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### CP27

### Spatio-Temporal Dynamics in the Olfactory System

Odors evoke a variety of stimulus specific spatio-temporal patterns which can be measured in vivo using Ca and voltage sensitive dyes. Reducing the number of dimensions of the spatio-temporal data allows for the description of the underlying biological mechanisms by low-dimensional dynamics. Based on biological principles a system of coupled nonlinear differential equations is developed which allows the reproduction of measured response characteristics.

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### CP29

### Turbulent Energy Dissipation for Forced Flow in a Slippery Channel

The bulk rate of energy dissipation is the power required to maintain a flow state. We consider the idealized situation of flow in a channel with slippery (no-stress) walls driven by an imposed shearing body force in the streamwise direction. The Navier-Stokes equations are used to derive a mini-max problem for an upper limit to the long-time averaged bulk power consumption, valid for laminar or turbulent flows. This variational problem yields rigorous bounds that are in qualitative agreement with the conventional cascade picture of turbulent dynamics. Moreover, mini-max problem can be solved exactly in the high Reynolds number limit. Quantitative results are compared to the results of direct numerical solutions of the Navier-Stokes equations for a particular "shape" of the driving force. Curiously, a component of the high Reynolds number solution of the variational problem is reminiscent of statistical aspects of the turbulent flow.

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### CP29

### Modeling the Slip of a Fluid at a Solid Interface at the Molecular Level

We study the slip of a fluid layer adjacent to a solid substrate by considering a phenomenological model of molecular interaction. The resulting model is a modified Frenkel-Kontorova (FK) equation incorporating both the forces between particles as well as the momemtum flux in the fluid which drives the flow. In the presence of thermal fluctuations, the FK equation can be rewritten as a Fokker-Planck equation and compared to a kinetic equation derived from the underlying dynamics governed by Newton's Laws.

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### CP29

### Electrohydrodynamically Driven Chaotic Advection in a Bounded Stokes Flow

We investigate Lagrangian chaos inside a dielectric liquid drop translating in a different dielectric in the presence of an axial modulated electric field. For sufficiently large field strengths an internal stagnation disk appears and particle trajectories, obtained numerically, exhibit chaotic behavior. We show that this phenomenon is caused by quasi-random changes in the adiabatic invariant of the flow, which occur as trajectories cross the stagnation disk, and estimate the characteristic time of mixing.

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**CP30**

**Long-Term Coexistence for a Competitive System of Spatially Varying Reaction-Diffusion Equations**

Spatial distribution of interacting chemical or biological species is usually described by a system of reaction-diffusion equations. In this work we consider a system of two reaction-diffusion equations with spatially varying diffusion coefficients which are different for different species and with forcing terms which are the gradient of a spatially varying potential. Such a system describes two competing biological species. We are interested in the possibility of long-term coexistence of the species in a bounded domain. Such long-term coexistence may be associated either with a periodic in time solution (usually associated with a Hopf bifurcation), or with time-independent solutions. We prove that no periodic solution exists for the system. We also consider some steady-states (the time-independent solutions) and examine their stability and bifurcations.

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**CP30**

**Modeling the Interaction of Key Players in Gradient Sensing in Dictyostelium**

Gradient sensing in eukaryotic chemotaxis refers to the cells perception of the external concentration field and transmittal of signal to the cytoskeleton. It results in the localized and amplified production of the lipid PIP3(3,4,5). We present a modeling framework, in the form of reaction-diffusion PDEs, describing the interaction of key enzymes and lipids, relevant to this. Within this framework, we analyze different mechanisms leading to this amplification and compare results with available experimental information.

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**CP31**

**Bifurcations of a Two-Degree-of-Freedom System with Dry Friction**

Consider self-excited motion of an oscillator caused by conveyor belt transport. Non-smooth periodic solutions arise in the planar system. They can be continued in the case of non-linear coupling to a second oscillator (energy absorber). There are interesting bifurcations among which a non-smooth manifold in the phase space.

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**CP31**

**Effects of Noise on Border Collision Bifurcations**

We consider the effect of noise on piecewise linear maps. For simple border-collision (or $C$) bifurcations, we show that the bifurcation point is smeared out. In the presence of multiple solutions, border collision bifurcations can be delayed. For significant noise levels, we find that the invariant density is found from a combination of solutions. Our results compare favourably with our exact solutions, where available. We discuss the application of this work to sonar.

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**CP31**

**Bifurcations in Grazing and Sliding Systems**

Piecewise-smooth systems can display a wide range of unique bifurcations. Normal form maps have been derived which explain these *grazing* and *sliding* bifurcations. These mappings are shown in general not to be piecewise-linear, rather they are characterised by a square-root, 3/2 or squared nonlinearity. We examine one-dimensional versions of these maps and classify the bifurcations that arise at the 'border-collision', and also investigate the period-adding scenario which can follow.

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**CP32**

**Self-Consistent Chaos in a Mean Field Hamiltonian Model**

Despite of the advances in the study of chaotic dynamics, the problem of Hamiltonian chaos in self-consistent systems is not well-understood. To address this problem we consider a mean-field self-consistent model consisting of an ensemble of globally coupled pendulums that describes marginally stable fluids and plasmas. We focus on the role of self-consistent chaos in the formation of coherent structures and violent relaxation, for finite-$N$ and $N \to \infty$,

where $N$ is the number of degrees-of-freedom [del-Castillo-Negrete, and Firpo, CHAOS 12, 496, (2002)].

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## CP32

### From Eigenmodes of $N$-Body Hamiltonian Dynamics to Van Kampen-Case Distributions for Landau Damping and Instability

For Hamiltonian dynamics with smooth mean-field interaction, the kinetic limit $N \to \infty$ commutes with time evolution over $[-T, T]$. We show how van Kampen-Case-like eigenmodes are needed by the $N$-particle-wave system to generate not only the analogue of Landau damping $\sim e^{\gamma|t|}$ $(\gamma < 0)$ but also unstable behaviour $\sim e^{\gamma|t|}$ $(\gamma > 0)$. This sheds further light on how $i\varepsilon$ prescriptions (absent in $N$-body dynamics) emerge in kinetic theory.

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## CP32

### High Dimensional Bowling

We study the dynamics of an $n$-dimensional symmetric ball rolling without slipping on an $(n-1)$-dimensional surface under the influence of a potential force. We examine, using geometrical methods, local and global properties of this generalization of the classical case, $n = 3$, which has recently been shown to contain an invariant measure. The system can be thought of as a "particle with a spin" providing a remarkable example of "hidden motions".

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## CP33

### Parametric Excitation in Nonlinear Dynamics

A basic problem in parametric dynamics is the behaviour of a one-mass system with two degrees of freedom, nonlinearly coupled, with parametric excitation in one direction. Assuming the internal resonance 1:2 and parametric resonance 1:2 we derive conditions for stability of the trivial solution by using both the harmonic balance method and the normal form method of averaging. If the trivial solution becomes unstable a stable periodic solution may emerge, there are also cases where the trivial solution is stable and co-exists with a stable periodic solution; if both the trivial solution and the periodic solution(s) are unstable we find an attracting torus with large amplitudes by a Neimark-Sacker bifurcation. Interestingly we find a Neimark-Sacker bifurcation by the numerical software package CONTENT and by averaging. In all cases we have good agreement.

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## CP33

### Scaling of the Chaotic Layer

The structure of the chaotic layer of a periodically perturbed one degree of freedom Hamiltonian system in the neighborhood of the saddle point is invariant under a discrete rescaling of the parameters of the system. The value of the rescaling constant is derived from Melnikov formula. This invarince extends to different systems, provided they belong to the same universality class. We derive the conditoins under which the two systems have the same structure of the chaotic layer (near the saddle), and confirm it with numerical examples.

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## CP33

### Microdisk Lasers, Billiards, and Subriemannian Geometry

Microdisk lasers have been invented and developed at Bell Labs over the past decade and the billiard model has been successfully used in designing the "optimal" cavity shape. We will show that a new class of billiard domains possessing an isolated caustic, which carries only periodic orbits, can be constructed using the methods of subriemannian geometry. We will also discuss some important implications of this construction for the microdisk lasers.

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## CP34

### Saddle-Node Hopf Bifurcation with Global Reinjection

We derive a $Z_2$-symmetric planar vector field that features a reduced saddle-node Hopf (SNH) bifurcation with global reinjection. This system is as simple as possible and can be viewed as a 'global normal form'. Our analytical and numerical investigations show that the global reinjection results in extra bifurcations that do not occur in the normal form of a (local) SNH bifurcation. As an application we consider a semiconductor laser with optical injection.

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## CP34

### Homoclinic Teeth and Excitability in Optically Driven Lasers

We investigate Shilnikov homoclinic bifurcations in a three-dimensional model of a semiconductor laser with injection.

The ensuing bifurcation curves, in the plane of the forcing strength and the detuning, form 'homoclinic teeth' which grow under the change of the important linewidth enhancement parameter. The bifurcation diagram involves curves of n-homoclinic orbits associated with the new phenomenon of multipulse excitability. We identify several codimension-two bifurcations, including Belyakov points, double homoclinic and double heteroclinic bifurcations.

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## CP35

### Diffusion-Limited Scalar Cascades

We study advection-diffusion of a passive scalar, $T$, by an incompressible fluid in a domain bounded by walls impermeable to the fluid. Variations in $T$ are produced by prescribing a steady nonuniform distribution of $T$ at the boundary. Because there is no flow through the walls, molecular diffusion, with diffusivity $\kappa$, is essential in lifting $T$ off the boundary and into the interior, where the velocity field acts to intensify $\nabla T$. We prove that the scalar dissipation rate – the volume integral of $|\nabla T|^2$ – vanishes in the limit $\kappa \to 0$, in violation of the fundamental premise of scaling theories for passive scalar cascades.

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## CP35

### Classification of Backward-Time Dynamics of the Space-Periodic Dissipative Pde's

It is known that forward in time all the dissipative dynamical systems converge to a certain compact invariant set, called the global attractor. Backward in time however, the dynamics of these systems vary widely starting with the space-perodic linear case with all the solutions behaving exponentially, and finishing with the 1-D space-periodic Kuramoto-Sivashinsky case with all the solutions blowing up in finite time. Notably, the 2-D space periodic Navier-Stokes Equations backward in time behave pretty close to the linear case. On the other hand, our result show that the Original Burgers Equations display competely different backward-time dymamics from both Navier-Stokes and Kuramoto-Sivashinsky cases.

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## CP35

### Higher Order Corrections to the KdV Approximation for Water Waves

In order to investigate corrections to the common KdV approximation to long waves, we derive modulation equations for the evolution of long wavelength initial data for the water wave and Boussinesq equations. The equations governing the corrections to the KdV approximation are explicitly solvable and we prove estimates showing that they do indeed give a significantly better approximation than the KdV equation alone. We also present the results of numerical experiments which show that the error estimates we derive are essentially optimal.

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## CP36

### Low Frequency Switching in a Transistor Amplifier

An audio frequency transistor was driven with high frequency signals (on the order of 1 MHz). In the amplifier output, not only were period doubling and chaos observed, but low frequency switching between different high period states was seen. The switching frequency was on the order of 5-10 Hz. Numerical simulations have also seen this switching.

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## CP36

### Analysis of the Dynamics of a Beamforming Receiver with Coupled Nonlinear Oscillators

We present an analysis of the dynamics of an analog signal processing approach that uses forced, coupled nonlinear oscillators. In particular, we outline a conceptual design for beamforming in phased arrays such as antennas or sonars that exploits the coupling between oscillators to improve beamforming performance. The approach enhances signal detection in the presence of noise and interference. The stability of the synchronized state depends on the forcing phase offset between oscillators and can be tuned so that all the elements only oscillate at the forcing frequency for a narrow range of offsets which correspond to a narrow mainbeam of incident signal angles. This enables discrimination between signals incident in the mainbeam from those in the sidelobes on the basis of a frequency-domain power spectrum, something not possible with conventional linear beamformers. We present a bifurcation analysis of the array dynamics and a stochastic simulation of its performance using a forced, diffusively-coupled Stuart-Landau equation.

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## CP36

### Split Personality of a Transistor

Bipolar and MOS transistors, which form common build-

ing blocs of electronic circuits, are represented by a simple nonlinear function $f : R^2 -> R^2$. This model is misleading in radio applications and should be replaced by nonlinear operators in $C$ or in $L^2$. The paper discusses the operator description, which to author's knowledge has never been presented before, the engineering techniques of describing it, and their justification via invariant manifolds.

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### CP37

### Coupled Pairs of Methyl Groups and Tunneling Quantum Roto-Breathers

Experiments performed by Fillaux *et al.* on 4-methyl-pyridine (4MP) at low temperatures imply localized energy transfers. We attempt to interpret the experimental data using a model based on quantum units of coupled pairs of rotors, which are coupled to their neighbors along chains. This accounts for the 3D structure of the crystal and all the relevant couplings in 4MP. It is proposed to interpret the observed localized energy transfers by means of tunneling quantum roto-breathers.

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### CP37

### Quantum Control Using Dynamical Systems Methods: Control of One and Two Interacting spin 1/2 Particles

In this paper we give constructive control algorithm for the system of one and two interacting spin 1/2 particles in magnetic field. The describing model are bilinear systems where states varies on finite dimensional complex Hilbert space of dimension two and four respectively. We make use of techniques from dynamical system theory (action angle coordinates) to derive the control law to steer the state of the system arbitrary close to any desired final configuration.

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### CP37

### Semiclassical Analysis of Long Wavelength, Multiphoton Processes

We study the dynamics of multiphoton transitions of atomic and molecular electrons under intense microwave irradiation. The quantum time-periodic Hamiltonian is analyzed with a general, non-perturbative method of quasi-adiabatic time evolution (Fox and Vela-Arevalo, *Phys. Rev. A* **(66)**, 2002). This powerful technique reduces the quantum dynamics to a non-autonomous system of ode's, which is numerically integrated. Existence of multiphoton transitions in the Rydberg atom is shown, and described in terms of Floquet states and quasi-energies.

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### CP38

### A Radial Continuum Equation for Three-Dimensional Rough Surface Growth

A stochastic partial differential equation for three-dimensional surface growth in the radial geometry is proposed. The equation reduces to the KPZ equation in the large radius limit. The kinetic roughening properties are studied with numerical techniques. Two distinct scaling regimes are discovered for the growth exponent. These results are used to discuss whether the radial continuum equation and three-dimensional off-lattice Eden growth belong to the KPZ universality class.

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### CP38

### Exponential Timestepping with Boundary Test for Stochastic Differential Equations

We present new numerical methods for stochastic differential equations. Successive time increments are independent random variables with an exponential distribution. The algorithms are efficient for escape-time problems, where large errors result from the possibility that a boundary is reached during a timestep although the process is within the boundary at both the beginning and the end of the timestep. A simple test is performed using the required conditional hitting probabilities. http://randomideas.org

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### CP39

### Attractive Bose-Einstein Condensates in a Double Well Potential

In recent work, Aschbacher et al. [2001] describe a regime in which minimizers of the Hartree energy functional lack the symmetry properties of the underlying two-body potential. We consider the simple 1-d model of a nonlinear Schrödinger equation with a double well potential. For this system, we observe the bifurcation of an asymmetric pulse from the original symmetric solution and characterize the stability of these pulses using the topological criterion of

Jones [1988].

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### CP39

### Bursting Oscillations in Optical Parametric Oscillators

Bursting oscillations, which are frequently observed in biological systems, feature bursts of rapid oscillations separated by steady-state intervals. Examples of such oscillations in optics are rare or cannot be simply described. Through a perturbative analysis, we show numerically and analytically that optical parametric oscillators subject to thermal effects exhibit subcritical elliptic bursting, a case relatively rare in biology. This result is confirmed by new experiments describing a variety of different bursting regimes.

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### CP39

### On the Modulational Stability of Gross-Pittaevskii Type Equations in 1+1 Dimensions

Modulational Instability in Bose-Einstein Condensates or: Can you Teach an Old Dog New Tricks ? Zoi Rapti University of Massachusetts Since the pioneering work in fluid dynamics/plasma physics, modulational instability criteria in nonlinear Schrödinger type equations are well-established. In this talk, we present a different (variationally motivated) approach to such criteria. Then, bearing in mind the experimentally motivated, "trendy" application of Bose-Einstein condensates, we examine similar questions in the presence of external (linear and quadratic) potentials by a combination of analytical (such as e.g.,linear stability, nonlinear transformations and variational methods) and numerical techniques.

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### CP40

### Universal Scaling of Lyapunov Exponents in Coupled Chaotic Oscillators

We have uncovered a phenomenon in coupled chaotic oscillators where a subset of Lyapunov exponents, which are originally zero in the absence of coupling, can become positive as the coupling is increased. This occurs for chaotic attractors having multiple scrolls, such as the Lorenz attractor. We argue that the phenomenon is due to the disturbance to the relative frequencies with which a trajectory visits different scrolls of the attractor. An algebraic scaling law is obtained which relates the Lyapunov exponents with the coupling strength. The scaling law appears to be universal.

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### CP40

### Phase Synchronization of Chaos in Coupled Nonautonomous Oscillators

Synchronization effects in two coupled double-well Duffing oscillators with parametric excitation in one of them are studied. Both one-well and cross-well chaos are always synchronized in phase, while hopping oscillations are completely synchronized. Synchronous windows of periodicity (intermittent synchronization) in one state (one-state synchronization) and two states (two-state synchronization) are observed in time series for certain values of the modulation frequency and amplitude.

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### CP40

### Synchronization for the Winfree Model of Coupled Nonlinear Oscillators: From Continuum to Discrete

We consider the synchronization of a system of $N$ nonlinear oscillators with mean field coupling and distributed natural frequencies. For a uniform distribution of oscillators, as $N \to \infty$ the stability boundary between locking and partial locking cannot be determined by Lindstedt's method due to a singularity in the results. We generalize the analysis to consider arbitrary distributions and show that for any finite $N$, the stability boundary can be uniformly approximated. However, as $N$ increases the coefficients of the perturbation solution grow unbounded and the interval over which the approximation is valid shrinks.

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### CP41

### Intermittency in a System of Self-Driven Particles

We describe the intermittent behavior appearing in the collective dynamics of a system of many self-driven particles, each moving with constant speed in the local particle flow direction (plus noise) [T. Vicsek *et al.*, Phys. Rev. Lett. **75**, 1226 (1995)]. In the ordered phase, there is a global flow which is lost during intermittent bursts. We solve a simple two particle model accounting for this behavior and construct a scaling argument that describes the many-particle dynamics.

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### CP41

### Analysis of a Model Describing Filaments Growth

We propose a simple model describing the growth of filaments in a system consisting of a large number of magnetic particles. Explicit solution for this model can be constructed. Based on this solution the filament size distributions depending on the dipole momentum of the particles and the thermal energy are obtained. Proposed approach works for some other systems describing cluster aggregation processes as well.

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### CP41

### Stability Analysis of Large-Scale Incompressible Flow Systems

We will present results of studies of flow instabilities in some interesting systems. Our approach has been to develop a general purpose library of bifurcation analysis algorithms that can be easily implemented with exisiting Newton-based codes. This "LOCA" library has been interfaced with a mature, massively parallel, finite element code for modeling incompressible reacting flows. This approach has enabled stability investigations of models of over 1 Million unknowns.

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### CP42

### Synchronizing Disparate Chaotic Systems Via Symbolic Dynamics

We extend the concept of generalized synchronization for coupling different types of chaotic systems, including maps and flows. This broader viewpoint takes disparate systems to be synchronized if their information content is equivalent. We use symbolic dynamics to quantize the information produced by each system and compare the symbol sequences to establish synchronization. A general architecture is presented for drive-response coupling that detects symbols produced by a chaotic drive oscillator and encodes them in a response system using the methods of chaos control. We include experimental results demonstrating synchronization of information content in an electronic oscillator circuit driven by a logistic map.

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### CP42

### Multiple Synchronization

A method is presented whereby multiple transmitter-receiver pairs of pairwise identical, chaotic dynamical systems may be simultaneously synchronized using a single scalar signal. The dynamical systems need not be related, and the transmitters evolve independently of one another. As for the signal, almost any scalar function of the transmitter state vectors may be used. Numerical simulation results are presented demonstrating simultaneous multiple synchronization achieved by this method.

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### CP42
### Transient Spatiotemporal Chaos

Wave-induced spatiotemporal chaos in the Gray-Scott model, an excitable medium based on cubic autocatalysis, is transient with an exponential increase of the average transient time with medium size. The collapse of this diffusion-sustained spatiotemporal chaos is initiated by intrinsic statistical spatial correlations that force the medium into the asymptotically stable steady state. Quasi-homogeneous transition states for the immediate escape of the medium from spatiotemporal chaos are investigated.

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### CP43
### Opening of DNA by Helicases

In cells, proteins called helicases open DNA. We model this process, focusing on different opening mechanisms (called "active" and "passive" in the literature). The motion of the helicase and the opening/closing of the DNA affect each other due to an interaction potential between them. Varying forms of the potential can change the unwinding rate by more than a factor of 10. We discuss the interaction potential which maximizes the rate of strand separation.

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### CP43
### Backfiring in Excitable Media and the Unfolding of a Heteroclinic Loop

Applied dynamical systems theory has shown how pulses can arise in excitable media. Instabilities of those have been observed in various experiments and related reaction-diffusion systems. In several cases secondary pulses grow out of the wake of a primary pulse. We show that in the Oregonator model for the Belousov-Zhabotinskij reaction a heteroclinic loop between an equilibrium and a periodic orbit arises and how its unfolding can help explain the observed phenomena.

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### CP43
### Asymmetric Partial Devil's Staircases

Partial asymmetric devil's staircases appear in many periodically stimulated excitable systems, for example axon forcing and excitement of the heart by the Sinus Node. It is demonstrated how such staircases can be obtained from piecewise-linear iterative maps with a discontinuity. It is further shown that a horizontal or a negatively sloped map segment, next to the discontinuity, is responsible for the staircase partiality. A hierarchy of partiality is found and shown to be related to the length of this segment.

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### CP44
### A Laser with Parameters That Vary Slowly in Space: Bifurcation Analysis of the Eckhaus Instability

In a pattern-forming system, slow spatial variations of parameters induce instabilities (the ramp-induced Eckhaus instability) that would not occur in a uniform medium. In optics, this problem is crucial because such nonuniformities are omnipresent. We present the experimental results and the corresponding modeling, that motivate the work. Then, in order to extract general features of the instability mechanism, we perform a numerical bifurcation analysis of the Eckhaus instability in a model amplitude equation.

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### CP44
### Transition from Hexagons to Spatio-Temporal Chaos in a Nonlinear Optical Cavity

We characterize the bifurcation sequence of a stationary hexagonal pattern in a prototypical nonlinear optical model. Bloch and Bloch-Floquet analysis show that space-time interplay leads to a mixture of spatial period multiplying and quasiperiodic scenarios (Hopf bifurcation at $\lambda_H/\sqrt{3}$, where $\lambda_H$ is the pattern wavelength, followed by Neimarck-Sacker at $\lambda_H/3$). A subsequent long-wavelength instability leads to chaotically oscillating peaks still located on the hexagonal lattice. Spatial order is completely lost probably through a crisis.

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### CP44
### Observation of Convective and Absolute Instabili-

**ties in An Optical System**

We study theoretically and experimentally the convective and absolute instabilities in a "real" system in presence of noise and with spatial non-uniformities. First we derive analytical expression of both thresholds for the ideal noiseless and spatially uniform situation. Then numerical simulations allow to determine a signature of those instabilities, that is applied to our experiments realised with a Kerr (nematic liquid crystal) medium subjected to a laser beam with tilted feedback.

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## CP45

### Nonlinear Dynamical Model of Small Group Decision Making

We present a model of small group decision making by foreign policy elites in which group member positions or opinions with respect to a given policy issue evolve in response to the influence of other group members and incoming information. The form of the model is guided by social psychology and cognitively-based approaches to foreign policy decision making. The model dynamics are implemented via a set of coupled nonlinear differential equations for the state vector of member opinions. Computational simulations of the model display a range of phenomena central to foreign policy decision making in the small group context.

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## CP45

### Two Parameter Optimal Control of a Nonlinear Dynamical Microeconomic Model

In this work, a nonlinear model of the process of production, storage, and sales of a consumer good has been simultaneously controlled by the rate of production and the price of the good. Attainable sets of controlled systems are investigated and the boundaries of these sets are studied. It is proved that only bang-bang controls with at most two switchings can lead to the boundary of the attainable sets. Shapes of attainable sets for different parameters of the model will be demonstrated using MAPLE.

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## CP46

### On Numerical Analysis, Normalization of Fields in Mis-Aligned Conductors Or Shells

We consider systems differential equations arising from Electromagnetic fileds in a shell/conductor may be made of nonlinear ferromagnetic material. We look for exact solutions via normalization and compare it to that of analytical results. If data available from experimental results, a comparison to exact solutions will be done. Further, we compute for total sheath losses due to heat, dissipation, other in electric machine layer winding.

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## CP46

### Receptance Coupling for High-Speed Machining Dynamics Prediction

We apply receptance coupling techniques to predict the tool-point frequency response for high-speed machining applications. Building on early work of Duncan, Bishop and Johnson, and more recent work of Ewins, et al., we develop an analytic expression for the frequency response at the free end of the milling cutter from: 1) an analytic model of the tool; 2) an experimental measurement of the holder/spindle sub-assembly; and 3) a set of empirical connection parameters. These parameters are extracted using nonlinear least squares estimation, from two measurements of the tool/holder/spindle assembly, at the longest and shortest tool overhang lengths. The assembly model can then be used to predict changes in the tool-point receptance for setup variations, such as tool length. The resulting tool-point frequency response is used to calculate the associated stability lobe diagram, which defines regions of stable and unstable cutting zones as a function of chip width and spindle speed and is used to select appropriate machining parameters. A description of the receptance coupling method, as well as a discussion of the system model and selected connection parameters, are provided.

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## CP46

### Modelling and Dynamic Response of a Damper with Relief Valve

A single piston hydraulic damper containing a bypass with a spring-loaded valve is investigated. This piecewise-smooth system produces many interesting dynamics. The valve motion is of interest in this talk, displaying rapid oscillations under sinusoidal piston displacement. Work by Hayashi et al found chaotic dynamics in a similar valve. This talk will show how to model the complication of an extra orifice and its implication on the dynamics. With

N.A.J. Lieven and A.R. Champneys.

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**CP47**

**Identification of Young's Elasticity's Modulus**

In this work, a partial differential equation is taken as a model. The vibration of a beam is taken. The equation will be solved in time with numerical methods based on the finite element method. The parameter estimation will be done by the minimisation of an output least square criterion. Young's elasticity's modulus will be estimated and studied. Models for this modulus will be presented.

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**CP47**

**Monodromy in the Resonant Swing Spring**

We show that an integrable approximation of the spring pendulum, when tuned to be in 1:1:2 resonance, has monodromy. Lynch and Holm (SIADS 1, p44) derived a differential equation to explain the stepwise precession of the swing plane. We show that the stepwise precession angle of the swing plane of the resonant spring pendulum is a rotation number of the integrable approximation. Due to the monodromy, this rotation number is not a globally defined function of the integrals. We prove that at lowest order it is given by $\arg(a + ib)$where $a$ and $b$ are functions of the integrals. The resonant swing spring is therefore a system where monodromy has easily observed physical consequences.

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**CP47**

**Longterm Dynamics for Equations Modeling Nonuniform Deformable Bodies with Heavy Rigid Attachments**

An important basic problem in solid mechanics is describing the motions of deformable bodies carrying heavy rigid attachments. I study a degenerate nonlinear partial differential equation with dynamical boundary condition that governs such motions for nonuniform bodies. My main result is proving that the corresponding dynamical system has an absorbing ball whose size is independent of the order of the discretization. This implies the existence of an absorbing ball for the infinite-dimensional dynamical system corresponding to the original degenerate partial differential equations and thereby serves as a critical step for establishing the existence of global attractors.

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**CP48**

**Nonlinear Control of Engine Speed and Air-Fuel Ratio in Automotive Systems**

The engine management scheme proposed in this paper, attempts to jointly control of engine speed and AFR (Air-Fuel Ratio) in a SI (Spark Ignition) engine in presence of modeling uncertainties. The goal of this approach is accurate control of the AFR to satisfy stringent emission regulations and at the same time, tracking control of the engine speed as a powerful means in the engine control unit that enables the vehicle to be a member of a platoon in an IVHS (Intelligent Vehicle Highway System) network. It is explored to use of nonlinear adaptive control as a means of precisely regulating the AFR and tracking the engine speed. A control oriented physics-based model for a port fuel injected engine equipped with an electronic throttle has been used, while the model parameters are adapted online. In the engine speed control stage, a two-state model is utilized to describe dynamics of the intake air and engine rotation. In this part, time variability of the parameter values, due to e.g. variations in the vehicle and road conditions, is considered and an adaptive controller estimates the parameters at any time. To account any change characteristics of the engine components and other variability in dynamic behavior of the engine, the intake manifold pressure and the crank shaft speed are estimated by a constant gain extended Kalman filter. In the AFR regulation stage, a two-state dynamic model is utilized to describe the liquid and vapor fuel mass flows into the intake manifold. Dynamic model parameters, i.e. evaporation time constant and fraction of the liquid fuel which is deposited on the manifold as a fuel film, are estimated on-line by an adaptive scheme that uses knowledge of the system dynamics and measurements of an EGO (Exhaust Gas Oxygen) sensor at the exhaust location. For fast correction of steady-state system errors, initial values for the parameters are fetched from static maps saved in the memory. To reach a more precise and robust AFR regulation and overcome unstructured uncertainties, such as unmodeled dynamics and disturbances, and to estimate immeasurable model states, including the liquid and vapor fuel mass flows, an asymptotic nonlinear observer is used. The stability study is proposed in each part and performance of the scheme is shown through simulation results.

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**CP48**

**Quadratic Equivalence: An Efficient Tool For Observability Analysis**

This paper deals with quadratic observability normal form for nonlinear discrete-time Single Input Single Output (SISO) system. At first linearly observable case is analyzed. Afterward, one dimensional linearly unobservable case is investigated. Finally, in some examples, the key roll of the so-called resonant terms is highlighted for the

analysis of the observability and observer design.

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## CP48

### On the Estimate of the Stochastic Layer Width for a Model of Tracer Dynamics

The motion of passive tracers in a two-dimensional periodic incompressible fluid flow may possess a chaotic behavior, known as chaotic advection. This can be visualized in phase space as orbits forming a chaotic layer around a hyperbolic fixed point, where diffusion and transport properties are manifested. A stream function is derived as a "two-mode" truncation from a two-dimensional Navier-Stokes problem, in order to better understand the properties of the tracer dynamics under the influence of the chaotic saddle existing in phase space. As a matter of fact the approximated stream function shows qualitatively the same dynamics as the full Navier-Stokes solution in the parameter region around the first bifurcations. By using an appropriate time-periodically driven stream function we compute its Poincare section and simulate the chaotic layer. This can be considered as a time-dependent Hamiltonian, and consequently we can use analytical methods, such as Melnikov theory in order to construct a separatrix map, by which we can derive an analytical estimate of the stochastic layer width. The obtained analytical results are compared with the numerical results finding a rather good agreement with the half width paralell to the shear flow. We believe that our results might help to better understand the validity of the separatrix map method for the analysis of the stochastic layer, especially when we trasform the original energy-time relations into phase-space relations.

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## CP49

### Pattern Formation on Three-Dimensional Superlattices

Reaction-diffusion systems in three-dimensions can undergo steady-state bifurcations to triply periodic patterns. This problem has been solved for systems with the periodicity of the simple, face-centered and body-centered cubic lattices [Callahan and Knobloch, Nonlinearity 10 (1997) 1179]. There are three more lattices that are related to the cubic lattices as the superlattices of [Dionne, Silber and Skeldon, Nonlinearity 10 (1997) 321] are to the square and hexagonal. We determine all axial isotropy subgroups, which thus have primary bifurcation branches.

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## CP49

### Scaling Laws for Damage Evolution in Disordered Materials: Numerical Aspects

Scaling laws derived from mesoscopic discrete lattice models are typically used for coupling the mesoscopic damage evolution with the continuum damage response and in determining the size effects on the constitutive response of materials. This study develops the scaling laws for damage evolution based on the Renormalization Group (RG) methodology. The developed scaling laws imply the existence of a finite critical fracture threshold, below which macroscopic fracture of an infinite system does not occur. This result is in contrast with earlier results based on power law curve fit expressions, wherein the critical threshold approaches zero in the limit of an infinite system. However, the existence of a finite critical fracture threshold may be associated with a critical crack size, below which macroscopic fracture of a specimen does not occur.
Numerical simulations based on two-dimensional triangular and diamond lattice networks substantiate the proposed scaling laws and are used to estimate the critical thresholds and the scaling exponents. The computational bottleneck involved in modeling the fracture simulations using large discrete lattice networks is that a new set of governing linear systems of equations need to be solved everytime a lattice bond is broken. This study presents an algorithm based on rank-one update of the matrix inverse for modeling the relaxation processes in disordered systems. Using the present algorithm, the computational complexity of solving a new set of linear system of equations after breaking a bond reduces to a simple *backsolve* (forward elimination and backward substitution) using the already LU factored matrix. This algorithm using the direct sparse solver is faster than the fourier accelerated iterative solvers such as the preconditioned conjugate gradient solver, and eliminates the *critical slowing down* associated with the iterative solvers that is especially severe close to the percolation critical points. Numerical results using random resistor networks for modeling the fracture and damage evolution in disordered materials substantiate that simulations using the present algorithm are much faster compared to the competent fourier accelerated preconditioned conjugate gradient solvers.
In fracture simulations using the discrete lattice networks, an ensemble averaging of numerical results is necessary to obtain a realistic representation of the lattice system response. In this regard, and in the case of very large lattice systems, the main advantage of the algorithm presented in this paper is that it provides an attractive technique wherein the matrix of linear equations can be LU factored on multiple processors using a *parallel* implementation at the beginning of the analysis, and then the factored matrix can be distributed to each of the processors to continue with independent fracture simulations as they only involve backsolve operations.

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## CP50

### Domain Optimization for Stochastic Diffusions

Consider a system $x(t)$ evolving according to an autonomous Ito stochastic differential equation. Associate to $x(t)$ an integral cost functional $u(x)$ depending upon the first exit time for $x(t)$ from a given domain, starting at $x$. The function $u(x)$ solves an elliptic partial differential equation. The process $x(t)$ could represent the state of a physical system or the wealth vector of an investment portfolio. Optimality conditions for this problem are provided in terms of first and second variations of $u(x)$ with respect to domain variations preserving an integral constraint.

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## CP50

### Positive Solutions Of Three-Point Nonlinear Second Order Boundary Value Problem

In this research we apply a cone theoretic fixed point theorem and obtain conditions for the existence of positive solutions to the three-point nonlinear second order boundary value problem

$$u''(t) + \lambda a(t) f(u(t)) = 0, \quad t \in (0,1)$$

$$u(0) = 0, \quad \alpha u(\eta) = u(1),$$

where $0 < \eta < 1$ and $0 < \alpha < \frac{1}{\eta}$. We prove four general theorems, in which we determine values for $\lambda$ that yield the existence of positive solutions. At the end of the paper, we apply our obtained theorems to several population growth models.

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## CP51

### Bifurcation with Icosahedral Symmetry

This paper analyses the steady state bifurcation with icosahedral symmetry. The Equivariant Branching Lemma is used to predict the generic bifurcating solution branches corresponding to each irreducible representation of the icosahedral group $\mathcal{I}_h$. The relevant amplitude equations are deduced from the equivariance condition, and used to investigate the stability of bifurcating solutions. It is found that the bifurcation with icosahedral symmetry can lead to competition between twofold, threefold and fivefold symmetric structures, and between solutions with tetrahedral, threefold and twofold symmetry. Stable heteroclinic cycles between solutions with $\mathcal{D}_2^z$ symmetry are found to exist in one of the irreps. The theoretical scenarios are compared with the observed behaviour of icosahedral viruses and free silver nanoclusters.

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## CP51

### Transition to High-Dimensional Chaos Through a Global Bifurcation

We study a transition to high-dimensional chaotic behavior ($d \approx 4$) in a system composed out of three unidirectionally coupled Lorenz oscillators. The transition involves a global explosion that creates a high-dimensional chaotic set, formed by an infinite number unstable of tori. The chaotic set becomes an attractor after a boundary crisis, and exhibits multistability in a range of parameters, coexisting with two symmetry related (stable) three-dimensional tori (the only attractors before the crisis). These two 3D-tori disappear after a saddle-node bifurcation in which they annhililate with two unstable three-dimensional tori.

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## CP52

### Direction of Coupling from Phases of Interacting Oscillators: An Information-Theoretic Approach

A directionality index based on conditional mutual information is proposed for application to the instantaneous phases of weakly coupled oscillators. Its abilities to distinguish unidirectional from bidirectional coupling, as well as to reveal and quantify asymmetry in bidirectional coupling, are demonstrated using numerical examples of quasiperiodic, chaotic and noisy oscillators. Applications of the method to cardiorespiratory data and EEG of epilepsy patients are demonstrated.

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## CP52

### Uncertainty Analysis of Dynamical Systems

Parametric and initial condition uncertainty is studied within a unified random dynamical systems framework. The notion of input measure of an observable is defined and its propagation to an output measure is studied by means of transfer operators. Uncertainty of these measures is defined in terms of their cumulative distributions. The developed formalism is illustrated through analysis of the effect of pitchfork bifurcation on uncertainty. General results on uncertainty of time-averages of observables are derived.

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### CP53

**A Study of Correlations in Systems of Coupled Soc Automata**

We consider systems of (SOC) sandpile automata which are allowed to weakly interact with one another, and discuss the emergence of statistical correlations in the avalanching behavior between the individual sandpiles. The nature of these correlations is elucidated through numerical simulations and analytical methods.

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### CP53

**Hybrid Systems Forming Strange Billiards**

Dynamical systems which involve both continuous and discrete (symbolic) variables are dubbed hybrid systems. By means of Poincaré map techniques we investigate a class of hybrid systems where the continuous part of the system evolution is simply linear. Even those show a rich variety of dynamical behavior, including unusual bifurcations and deterministic chaos. Hybrid models of the described type are applied in the modeling of manufacturing systems but also generically describe the dynamics of charge density fronts in semiconductor superlattices.

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### CP54

**Periodic Driving of Turbulence**

We design tools to characterize three important characteristics of turbulence: structures-within-structures acting on each other in different time scales, the typical intermittent amplitude bursting of the oscillations, and its turbulent complexity. We apply these tools to show that the injection of a RF wave into the plasma edge of the TCABR tokamak decreases turbulence, although not completely destroy it. We also conclude that complexity of this type of turbulence should be mainly due to the multi-scaling self-similar character and not due to an usual belief that turbulence has an uncountable number of different interlocking structures (eddies).

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### CP54

**Coherent Structures and Turbulent Drag Reduction in Viscoelastic Flows**

Traveling-wave flows have recently been found that capture the main structures of the turbulent buffer layer. We show that the effects of polymer addition on these "exact coherent states" closely mirror those observed experimentally: structures shift to larger length scales, fluctuations are altered and drag is reduced. Lagrangian chaos in the velocity fields plays a key role in the drag reduction mechanism. These results support the view that these coherent states underlie near-wall turbulence.

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### CP54

**Local Stable Manifold for the Bidirectional Discrete-Time Dynamics**

We show the existence of a local stable manifold for a bidirectional discrete-time nondiffeomorphic nonlinear Hamiltonian dynamics. This is the case where zero is a closed loop eigenvalue and therefore the Hamiltonian matrix is not invertible. In addition, we show the eigenstructure and the symplectic properties of the mixed direction nonlinear Hamiltonian dynamics. As a consequence, we show the existence of a local solution to the Dynamic Programming Equations, the equations corresponding to the dicrete-time optimal control problem.

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### MS1

**Control and Synchronization of Homoclinic Chaos and its Implication for Neurodynamics**

Homoclinic spike trains have been intensively investigated for single mode CO2 lasers ; however, their occurrence has a more general significance insofar as this scenario fits the main aspects of action potentials in neurons. Stabilizing homoclinic trains has therefore a relevance for neural communication and synchronization, which seems to be the universal time code for perceptions. The core dynamics of homoclinic chaos is represented by the passage through a saddle point, in which neighbourhood the system susceptibility (response to an external perturbation) is very high and hence it is very easy to apply a control . A few aspects of regularization of homoclinic chaos are covered, such as, synchronization by an external pace-maker, DSS

(delayed self-synchronization), bursting, and NIS (noise induced synchronization). Such a general scenario is compared with specific neurodynamic models; moreover the coupling of many homoclinic chaotic systems in 1D or 2D chains is studied both for couplings above a percolation threshold ,where spontaneous synchronization patterns occur ,and for weak couplings, where synchronization requires an external stimulus

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### MS1
### Experimental Characterization of the Transition to Phase Synchronization in Homoclinic Chaos

We investigate the transition route to phase synchronization in a chaotic laser with external modulation. Such a transition is characterized by the presence of a regime of periodic phase synchronization, in which phase slips occur with maximal coherence in the phase difference between output signal and external modulation. We provide the first experimental evidence of such a regime, and demonstrate that it occurs at the crossover point between two different scaling laws of the intermittent-type behavior of phase slips.

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### MS1
### Phase Synchronization of Plasma Dynamics

General aspects of plasma discharges phase synchronized with different oscillators will be introduced. In particular, experimental techniques for real time observation of phase synchonization between plasma and Chua oscillations will be discussed. Also, numerical results, based on model equations, in good agreement with the experimental measurements will be presented.

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### MS1
### Phase Synchronization of Laser Dynamics

Recent theoretical and experimental advances have made it possible to detect and explore phase synchronization and complex relationships between coupled laser systems. The response of lasers to a wide variety of driving signals, ranging from constant and simply periodic to chaotic and noisy, are observed, and reveal intricate dynamical behavior, some of which remains to be explained fully. Possible applications of such phenomena will be outlined.

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### MS2
### Morphological Instabilities and Additive-Induced Stabilization During Electrodeposition

The surfaces of electrodeposited metals grown from baths without additives are typically rough, while the addition of certain additives can drastically suppress this roughening. We first examine how this roughening, associated with a morphological instability, depends on bath composition and growth rates. Next, we propose a mechanism by which additives can reduce or suppress this instability. We predict the experimental conditions under which instabilities can be suppressed by the additives, in good correspondence with experimental observations.

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### MS2
### Models for Selective Area Epitaxy

We developed mathematical models for semiconductor crystal growth on a substrate covered by the mask material with windows where the substrate is exposed to the vapor or liquid. In vapor phase growth model, the surface diffusion is assumed to be the main transport mechanism; diffusional growth from liquid phase is enhanced by applied electric current through crystal/melt interface. The motion of crystal surface in 2D is resolved by a finite-difference, front-tracking methods. Lateral overgrowth of crystal onto the mask as in experiments is found, as well as the comparable crystal shapes.

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### MS2
### Convective Instability During Step-Flow Epitaxial Growth

We examine an epitaxial crystal growth model in the context of absolute and convective instabilities and show that a

strain-induced step bunching instability can be convective. Using analytic stability theory and numerical simulations, we study the response of the crystal surface to an inhomogeneous deposition flux that launches impulsive and time-periodic perturbations to a uniform array of steps. The results suggest a new approach to morphological patterning at the nanoscale.

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### MS2
### Some New Tools for Simulating Epitaxial Growth

In this talk I will discuss a hybrid scheme for simulating epitaxial growth that combines two well-established models. Most of the crystal surface is well approximated by a homogeneous diffusion process. These homogeneous regions are separated by narrow regions which are better modeled using inhomogeneous random walks. In the hybrid scheme, the latter regions are simulated using Monte-Carlo methods.

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### MS3
### Classification of Bursting in Mappings

We classify possible mechanisms of bursting behavior in mappings: We identify 3 distinct types of bursting in one-dimensional mappings and 20 distinct types in two-dimensional mappings. We show that various bursters can interact, synchronize, and process information differently. Our study suggests that bursting in mappings does not comprise only a few isolated examples, but a robust nonlinear phenomenon.

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### MS3
### Modeling of Spiking-Bursting Neural Behavior Using Two-Dimensional Maps

A simple map model that replicates the dynamics of spiking and spiking-bursting activity of real biological neurons is considered. The mechanisms behind generation of spikes, bursts of spikes, and restructuring of the map behavior are explained. The dynamics of two coupled maps which model the behavior of two electrically coupled neurons is studied and compared with the results of experimental studies of chaos synchronization in real biological neurons.

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### MS3
### Canards and Chaos in Some Slow-fast Maps

The effect of canards' influence on the global dynamics in a number of slow-fast 2D maps modeling the dynamics of neurons is studied. A special emphasis is put upon the nonlocal transformations of the stable unstable canardic manifolds, and continuation of the invariant circle originating through the Andronov-Hopf bifurcation for maps. We argue that the breakdown of the invariant circle is caused by the hetoroclinic crossings of the above manifolds leading to chaos existing within an extremely narrow parameter range.

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### MS3
### Bursting as an Emergent Phenomenon in Coupled Maps

A two-dimensional map exhibiting bursting behaviour is examined. Model parameters are changed so that the bursting behaviour is destroyed. We show that bursting can be recovered in a population of such nonbursting units when they are coupled via the mean field. The phenomenon is explained with a geometric bifurcation analysis. The analysis reveals that emergent bursting in the network is due to coupling alone, and that heterogeneity in the model parameters does not play a role. These results are contrasted with results of analogous studies of emergent bursting in systems of ODEs.

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### MS4
### Correlated Firing and Delayed Feedback Memory Effects in Neurons

We discuss two memory mechanisms in simple neuron models. The first concerns the regularization of the firing pattern due to correlations between firing intervals in an integrate-and-fire model. Negative correlations due to refractoriness as well as positive correlations due to slowly varying noise processes are shown to determine the time scale over which the spike train is most regular. Consequently, signal detection and information transfer are enhanced on this time scale. We also show that long range positive correlations alone can produce an optimal time scale. The second memory mechanism arises from delayed feedback. We present recent results on analyzing delayed feedback in a simple thresholding system which emits a spike whenever the noisy voltage crosses a threshold. We show that this system has a resonant frequency that depends on the polarity of the feedback, and discuss how

bifurcations can be caused by changing the noise intensity. Comparisons between this system and others we have recently analyzed (bistable neuron and leaky integrate-and-fire neuron with delayed feedback) will be presented.

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### MS4
### Fast Control using Delayed Feedback

How can neural control in a noisy environment be maintained on time scales shorter than the time delay ("fast control")? Models in the form of stochastic delay differential equations together with experiments involving human balancing tasks and invertebrate neural circuits suggest that fast control requires feedback mechanisms that are tuned near instability. These observations support suggestions that critical phenomena play an essential role in the neural control of balance and movement.

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### MS4
### Effect of Time Delayed Feedback on Coherence Properties of Chaotic and Noisy Oscillators

We consider chaotic and noisy oscillators with time-delayed feedback. Our main interest is in the coherence properties of the processes, characterized by the phase diffusion constant. We demonstrate that delay in Lorenz and some other chaotic systems can lead to a drastic reduction of phase diffusion, i.e. to nearly coherent chaotic oscillations. A theory is developed based on the time-delayed Langevin equation for the phase, its statistical properties are found in the gaussian approximation.

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### MS4
### Noise-induced Dynamics in Bistable Systems with Delay

In non-equilibrium systems, noise is known to produce surprizing effects such as noise-induced phase transitions, stochastic resonance, etc. In this talk, we will consider noise-induced dynamics systems with memory using an example of a bistable system with delayed feedback. For small noise and magnitude of the feedback, the problem can be reduced to analysis of the two-state model with certain transition rates which depend on the earlier state of the system. In this two-state approximation, we find analytically the autocorrelation function, the power spectrum, and the linear response to a periodic perturbation. They show a very good agreement with direct numerical simulations of the original Langevin equation. The power spectrum has a pronounced peak at the frequency corresponding to the inverse delay time, whose amplitude has a maximum at a certain noise level, thus demonstrating coherence resonance. The linear response to the external periodic force also has maxima at the frequencies corresponding to the inverse delay time and its harmonics.

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### MS5
### Growth Induced Instabilities in Elastic Materials

The effect of growth in the stability of elastic material is studied. The formalism of exact elasticity and incremental deformation is adapted to allow the possibility of growing elastic materials . Results concerning elastic shells is given. This example can mimic the growth of solid tumors.

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### MS5
### Supercoiling Dynamics of Growing Filaments

To model the supercoiled structures exhibited by growing filamentous bacterial colonies, we formulate a theory for growing elastic filaments with bending and twisting resistance in a viscous medium. We study a filament with preferred twist, closed into a loop. Growth depletes twist, inducing twist strain, which eventually causes supercoils. We study this pattern-formation process with linear stabil-

ity analysis and numerical simulations.

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### MS5

### Growth and Form of Filamentary Micro-organisms

Filamentary organisms ranging from the prokaryotic actinomycetes to eukaryotic fungi are ubiquitous and important in Nature. During their complex growth cycle some actinomycetes can produce antibiotics, while some fungi are capable of mechanically degrading their local environment. This talk will describe biomechanical models of filamentary (hyphal) growth in which the organism is described, using large-deformation elasticity theory, as a pressure driven bioelastic membrane incorporating a growth mechanism. The theoretical and numerical analysis shows that plausible modeling assumptions lead to self-simliar filament growth.

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### MS5

### Surface Stress and Growing Elastic Bodies

We derive two new equations associated with the growth of elastic bodies in which *surface stress* plays a role. Surface stress arises from a dependancs of the surface energy on the local stretch of the surface. Distinguishing between *acretive* effects (i.e. growth) and deformational effects is the main challenge in the derivation. We also present a linear stability analysis of the associated *fingering* instabilities of a planar front. This extends the well known results of Asaro-Tiller-Grinfeld to the surface stress setting.

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### MS6

### Use of Python for Normal Form Analysis in Phase Space Transition State Theory

In this talk, the primary mathematical interest is in Hamiltonian systems in three or more degrees of freedom, having equilibria of (saddle-centre-... -centre)-type and their analysis, based on a normal form transformation about such equilibria. The normal form makes explicit the existence of a family of normally hyperbolic invariant manifolds which, for an n-DoF Hamiltonian, have the topology of (2n-3)-spheres and act somewhat as "big saddle points" for the system; Their stable and unstable manifolds have sufficient dimensionality to act as barriers (high-dimensional separatrices) in the constant energy surfaces and are thus the key to understanding how the phase space is partitioned into regions of qualitatively distinct behaviour. For the analysis of these systems and the associated high-dimensional geometrical objects, we have found Python to be extremely useful. Calculations involving normal form maps of high order are computationally intensive (the maps are expressed as polynomials with a large number of coefficients), so it is more efficient to code these maps in a language such as C++, however it is much more convenient to structure high-level computations using the maps in a language like Python, using wrapper code to call the underlying C++ implementation. Python also provides a convenient environment for writing code to drive visualisation frameworks (for example, the Visualisation Toolkit, VTK) for the visualisation of high-dimensional objects, and for writing simple user interfaces.

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### MS6

### Run-time Integration of Nonconforming Finite Elements and Visualization via Scripting

We discuss the run-time integration of a finite element code with visualization software via scripting. Both the solver and the visualization are C++ classes wrapped into Python via Swig. The visualization is handled by a new package, Tiresias. This package, built on top of VTK, uses a nonconventional approach to visualization in that it takes data readily accessible from the finite element code (reference mappings and local nodal values) to produce color-map plots for both conforming and nonconforming finite element data.

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### MS6

### Python for Climate Modelling

The ability to address grand-challenge problems in climate simulation is as much limited by inflexible model architecture as it is by sheer computing power. An investigator wishing to tackle an innovate problem that requires modifications of an existing model typically faces months of working up a steep learning curve before the first results can be obtained. To address this problem, we at the Climate Systems Center have been exploring the prospects of writing climate models that take the form of high-performance toolkits that can be assembled into full working models using Python as the basic glue and control structure. In this talk, I will review the features of Python that make it attractive for this purpose, proved some specific examples of the use of Python in building simplified climate models and scripting complex climate simulations, and discuss future developments needed to bring the program to completion.

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**MS6**

**A Python Based Computational Environment for the Dynamical Systems Analysis of Transport in Geophysical Flows**

In this talk we describe our computational environment for the dynamical systems analysis of transport in geophysical flows. Python is a good language for research into dynamical systems methods because the clear syntax, rich set of primitive datatypes (Python lists are tailor-made for storing growing invariant manifolds with no programmer overhead) and interactive development environment greatly reduces the cost of experimenting with ideas compared to C++ or Fortran. Object-oriented programming, especially with Python's dynamic type system, facilitates code reuse - the same methods can easily be used on a variety of problems, and garbage collection greatly simplifies working with complex data structures. The Numeric library makes the resulting code competitive with C for many grid-related problems, at least to the extent that speed has only recently come to be a concern, now that our code base is more-or-less stable, and the ease of linking Python with C means that we need only recode a handful of bottlenecks. The availability of MPI bindings was an important factor in choosing the language - even though we have not yet used it, we will, and we could not consider a language without such bindings.

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**MS7**

**Almost collision solutions of the 3 body problem**

We use the Levi-Civita regularization to study almost collision solutions of the elliptic and general planar 3 body problem. Using variational methods we construct orbits shadowing chains of collision solutions satisfying certain natural conditions. These results are an extension of classical results of V.M.Alexeyev.

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**MS7**

**Persistence of heteroclinic orbits for billiards and twist maps**

We consider the billiard motion inside a $n$-dimensional ellipsoid $Q$ with one diameter. The diameter is a hyperbolic two-periodic trajectory whose stable and unstable invariant manifolds coincide, so that there is a $n$-dimensional set of homoclinic billiard orbits inside $Q$. We prove that there exists a positive integer $l(Q)$ such that under any $C^3$-small perturbation of $Q$ persist at least $l(Q)$ primary homoclinic billiard orbits. The quantity $l(Q)$ runs between six (for prolate ellipsoids) to $8n$ (for generic ones), and is optimal for generic ellipsoids. The proof relies on the fact that billiard maps are twist maps. In fact, the bound $l(Q)$ is deduced from a more general bound $l(f)$ for twist perturbations of a twist map $f$ with a couple of hyperbolic periodic sets whose stable and unstable invariant manifolds have a clean intersection along submanifolds verifying some compactness and finiteness conditions.

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**MS7**

**On resonances and energy surfaces**

A framework for understanding the global structure of near integrable n d.o.f. systems is proposed. It consists of plotting energy-momentum bifurcation diagrams and branched surfaces, which are higher dimensional generalizations of the Fomenko-Oshemkov graphs. The relation between bifurcations in such plots, topological bifurcations of the energy surfaces and resonances is established. For some classes of systems this leads to a full qualitative description of the near-integrable dynamics, revealing where instabilities are expected.

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**MS7**

**Putting resonances at work: resonance phenomena and control**

We discuss using the capture into resonance as an efficient tool to control near-integrable dynamical systems, if the interaction between an unperturbed system and a weak periodic perturbation (a wave) is purely resonant. When a particle approaches the resonance we apply short control pulse to force the capture. Captured particles are transported by the wave across energy levels. We apply the second pulse to release a particle from the resonance at the desired energy level.

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## MS8

### Bubbling Bifurcations

Bubbling is a form of intermittent bursting that can occur in perturbations of a dynamical system with a weakly stable invariant submanifold – one whose basin of attraction has positive Lebesgue measure but is "locally riddled". I will discuss different types of bifurcations that can lead to bubbling and summarize past and recent results on the size and frequency of bursts near the bifurcation parameter values. The results are relevant to the synchronization of coupled chaotic systems, where bursting represents temporary loss of synchronization.

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## MS8

### Synchronization of Noninvertible Systems

The theory of invariant manifolds plays a fundamental role in the study of synchronization between systems with complex behaviors. The usual theory of invariant manifolds can also be extended to the case of noninvertible systems by considering inverse limits. Since the structure of the inverse limit spaces can be extremely complex, information about the synchronized state may be difficult to obtain by this indirect approach. The focus of the presentation will be the development of constructive techniques for the description of the synchronization set, and the study of bifurcations that can be expected in this context. Finally implications about the dynamical nature of weak synchrony and practical methods for the detection of such weakly coherent states will be discussed.

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## MS8

### Multi-scale Continuum Mechanics: Finding Constrained Invariant Sets

We present a method to construct stable and unstable invariant sets, where the invariant sets are constrained to lie on a slow invariant manifold. The method applies to any system with disparate time scales where a slow manifold approximation can be found. The construction of stable and unstable sets constrained to an unstable slow manifold is exemplified in a structural-mechanical system consisting of a pendulum coupled to a viscoelastic rod.

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## MS8

### Singularities in the Solution Set of an Optimal Control Problem

The inverted pendulum on a moving cart is an ideal example to investigate the solution structure of a nonlinear optimal control problem. Since the dimension of the pendulum system is small, it is possible to illustrate the concepts with various pictures enhancing the understanding of the topology of the solution set. We investigate how the optimal cost depends on the initial conditions. The graph of this *value function* contains regions where the solution set is non-smooth. The mechanism that controls the non-smoothness can be explained via a transformation that lifts the set to a smooth manifold in a higher-dimensional space.

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## MS9

### Competitive Exclusion in Discrete-Time Deterministic and Stochastic Epidemic Models with Multiple Pathogens

The dynamics of discrete-time, deterministic and stochastic SIS epidemic models with multiple pathogen strains in a single population (single patch) and in two populations (two patches) are studied. In the model with two patches, it is assumed that infected and susceptible individuals disperse between the two patches. The deterministic models are systems of difference equations whereas the stochastic models are discrete-time Markov chain models. It is shown that the basic reproduction numbers for each strain are important determinants of the asymptotic behavior. Analytical and numerical results show that a competitive exclusion principle applies to the single patch model. The strain with the largest basic reproduction number is the one that persists and outcompetes all other strains provided its magnitude is greater than one. However, in the two-patch epidemic model, where infected individuals move between the two patches, it is possible for more than one strain to persist in each patch; spatial heterogeneity increases the possibility of pathogen coexistence.

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## MS9

### Anatomy of a Chaotic Attractor

A system of difference equations (a nonlinear Leslie model) called the LPA model has played a fundamental role in a decade long study of nonlinear population dynamics. In one study, the model predicted a route-to-chaos that was later documented in laboratory experiments using insect populations. A population from this experiment has ex-

hibited chaotic dynamics for over 95 generations (8 years). In this talk I will describe how model predicted patterns in the chaotic attractor explain subtle patterns observed in this data. The study involves a consideration of stochasticity and state-space lattice effects and shows how, in this case, the observed dynamics are a stochastic blend of continuous state-space dynamics (including saddle cycles and chaos) and discrete, latticed state space periodic attractors. These experimental results suggest that such a mix of entities might be an important component in observed fluctuations in ecological data.

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**MS9**

**Monarch Butterfly Metapopulation Dynamics**

The North American Monarch butterfly, Danaus Plexippus Lepidoptera, exhibits one of the most spectacular natural migration phenomena in the world. However, it is considered an endangered phenomenon because scientists fear that the incredible Monarch migration pattern may not last beyond the next decade. In this talk, we use a simple metapopulation model to study the effects of migration and intraspecific competition on the Monarch butterfly population dynamics. By their own nature, simple models cannot incorporate many of the complex biological factors. However, they often provide useful insights to help our understanding of complex processes. We focus on compensatory (equilibrium) and overcompensatory (oscillatory) dynamics, two types of density dependent intraspecific competition for resources.

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**MS9**

**HIV Epidemics**

HIV entered the U.S. gay population from African sources. It thus is surprising that the U.S. gay epidemic exploded over a decade earlier than the African one. Using difference equation models we show how the same transmission dynamics explain the fast gay epidemic and the slow African one. The growth of HIV in a population is the combined effects of a fast wave of HIV transmission by newly infected persons (primary infection) and a slow wave of transmission by persons late in their illness (symptomatics). The propagation of HIV in a population is the combined effects of fast and slow transmission waves. The fast transmission wave was a significant factor in the spread of HIV among gays but not in the South-African epidemic. The difference in the two epidemics can be explained by ten-fold smaller effective contact rates (infectivity times frequency of contact) in the African epidemic compared to the gay epidemic. Joint work with Frederick Suppe (Texas Tech Univ) and Brandy Rapatski (U of Maryland)

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**MS10**

**Equilibira of Finite Elastic Rods with Intrinsic Curvature**

We consider finite elastic rods having intrinsic curvature, with things like telephone cords in mind. We analyze the boundary value problem corresponding to a straight (stressed) reference configuration and clamped ends, where one end has mobility along the undeformed axis of the rod. A rigorous bifurcation analysis reveals the existence of two kinds of "buckled" equilibria - helical states and so-called helical perversions. We also present computational results, revealing the global structure of the solution set. (This is joint work with G. Domokos)

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**MS10**

**Stability of a Twisted Elastic Strut**

The index is calculated for the isotropic and anisotropic elastic strut subject to imposed twist and endloading. The index of unbuckled equilibria of this two-parameter problem is determined directly using a conjugate point test that exploits the fact that a parameter appears linearly in the second variation. Sheets of buckled equilibria are also generated by computing a coordinated family of one-dimensional branches by parameter continuation. The index of each buckled equilibrium is determined using a numerical implementation of conjugate point theory for constrained problems.

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**MS10**

**Stability of a Buckling Rod in a "Soft Wall" External Field**

We consider the stability of equilibrium configurations of elastic rods buckling against an external field modeling a "soft" wall, focusing in particular on the approach to the limiting case of an impenetrable "hard" wall (as has been studied recently, e.g., by Holmes, Domokos, et al, as well as van der Heijden et al). Stability in the soft-wall case may be determined via an extension of classical conjugate point theory, and the hard-wall limit is used to impute the stability of hard-wall configurations (for which a conjugate point theory seems more difficult to derive). We consider both 2D and 3D rods, as well as clamped-clamped and pinned-pinned boundary conditions (the latter case requiring a more complicated conjugate point computation, since the classical theory assumes Dirichlet-Dirichlet

or Dirichlet-Neumann boundary conditions)

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### MS10

### Thermal Fluctuations of Small Rings of Intrinsically Helical Elastic Rods

The nature of the normal modes of rings formed from intrinsically helical elastic rods is described. It is shown that the writhe distribution in a collection of thermally fluctuating rings of this type can be deduced from the dependence of the frequencies of the normal modes on the intrinsic geometric torsion of the rods. Increasing the intrinsic curvatre broadens the writhe distribution, a result related to the stability properties of the equilibrium circular configuration.

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### MS11

### Chaotic and Turbulent Dynamics of Nonlinear Waves in One-dimension

We study the chaotic and turbulent dynamics of one-dimensional nonlinear waves. We will address the issue of effective stochastic equations for the long-time and large-scale dynamics and associated invariant measures.

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### MS11

### Application ofWeak Turbulence Theory to Fermi-Pasta-Ulam Model

We adapt weak turbulence (WT) theory in an attempt to describe the nonequilibrium evolution of the energy spectrum starting from a large-scale excitation in the (alpha) Fermi-Pasta-Ulam (FPU) model. While this system is weakly nonlinear and dispersive, and therefore formally amenable to WT theory, a standard application of the theory misses some important dynamical aspects. We explore the reasons behind these shortcomings, analyze some remedial modifications, and describe the implications for WT theory in other applications.

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### MS11

### Weak Turbulence and the Garrett-Munk Spectrum of Internal Waves in the Ocean

Wave turbulence formalism for long internal waves in a stratified fluid is developed, based on a natural Hamiltonian description. A kinetic equation appropriate for the description of spectral energy transfer is derived, and its self-similar stationary solution corresponding to a direct cascade of energy toward the short scales is found. This solution is very close to the high wavenumber limit of the Garrett-Munk spectrum of long internal waves in the ocean. I will conclude by showing how to generalize our results for low frequency waves, and by comparing our prediction with modern oceanographic measurements.

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### MS11

### Resonant Energy Transfer, Breaking Waves and Mixing

Abstract not available at time of publication.

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### MS12

### Efficient Control Problem

Abstract not available at time of publication.

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### MS12

### Dynamical System and Non-linear Control Therory

nonlinear optimal control problem: To consider nonlinear optimal control problems where both the defining equations and the performing index are nonlinear- to consider necessary and /or sufficient conditions of existence of solutions and make some comments. To discuss their applications in Fishery and pest management problems with linear performing index and sometimes also with some nonlinear performing index-to apply technique of continuous dynamic programming for some general type of nonlinear performing index in nonlinear fishery problem. To consider special linear quadratic problem, its advantage, its extension to infinite dimensional spaces. To consider General linear quadratic problem, its advantage, its extension to a generalised Hilbert space newly introduced and also other types of generalisations for such general linear quadratic problem.

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### MS12

### Spatiotemporal Model and Its Application to Methane Emission System

A natural continuous phenomenon can be described by a system of Ordinary differential equations, which in turn gives rise to a dynamical system. Flow of this dynamical system represents the change of phase with respect to time. The long-term behavior in this case, is called a temporal dynamics of the system and the corresponding model is called temporal model. Within this temporal behavior of phase portrait, some parameters also exhibit spatial

variations. These parameters when considered as spatial variables, the temporal model changes to a spatiotemporal one. Obviously, a complex processes is responsible for that spatial variability, so lots of other parameters may controlling that processes. We start with some of them, which agree our experimental data. Obviously, complex phenomenon cannot be controlled by of ODEs only. In addition a set of partial differential equations will be needed to explain this complex processes and its behavior. These systems of PDEs together with the earlier ODEs constitute the spatiotemporal model. The corresponding dynamics considered is called spatiotemoral dynamics. Methane emission phenomenon from soil is spatiotemporal in nature. This phenomenon is a combination of two processes one is methanogenesis and other is biological oxidation of methane. Since both the processes depend on soil temperature, soil water content etc. and they have the diffusion and advection (bulk flow) property, so the entire phenomenon becomes spatiotemporal in nature. Monod kinetics is considered in different forms for both the processes to form the temporal model. Parameters like specific biomass growth is considered here as spatial parameters and its rate of change with respect to time is expresses by PDE with the help of Soil temperature and Soil water content and their diffusion properties. The final model describes the total behavior of methane emission from soil.

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### MS12

### Difference Equations and Dynamical Systems with Some Applications

Most of the models arising in practice cannot be completely solved by analytical techniques and thus numerical simulations are of fundamental importance in gleaning understanding of dynamical systems. Hence it is crucial to understand the behavior of numerical simulations of dynamical systems in order that we may interpret the data obtained from such simulations and in order to facilitate the design of algorithms, which provide correct qualitative information without being unduly expensive.

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### MS13

### Biological-Physical Interactions at the Size Scale of an Individual Copepod

The biological-physical interactions at the size scale of an individual copepod refers to that the copepod actively controls the surrounding viscous water-flow by adopting suitable swimming behaviors according to environmental conditions. Essentially, the changes in swimming behaviors result from the changes in the force and power the copepod exerts on the water. A self-propelled body model, i.e. coupling the Navier-Stokes equations with the dynamic equations for the copepods body, is imperative to tackling this problem.

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### MS13

### Vortex Swarming of Biological Agents

Although swarm theories of self-propelled agents have become of great interest to theoretical physicists lately, well-defined swarming experiments using real biological agents have been problematic up to now. We present the results of lab experiments with the zooplankton Daphnia that show the entire range of behaviors from single agent to collective motions of a swarm with a single animal, and can be observed to perform a fascinating vortex-swarm under certain circumstances.

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### MS13

### Emergent Properties in Biology: Are Fish Schools an Appropriate Model?

Animal aggregation is a pervasive phenomenon. In fish, over half the 20,000 known species school. Individuals make decisions about when and how to respond based on a complex combination of internal and external state. The resulting group behavior is expressed as emergent pattern - architecture, coordinated movement, and task completion - not predictable from individual member movement. Whether emergence is an epiphenomena of gregariousness, or the result of selection at the individual and group level will be discussed.

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### MS13

### Stepping Through the Water

What are the smallest steps one can use to build up a simulation representing the world of the zooplankton? There may be series of steps linked together being highly correlated units. Based on hours of observations I like to show the different steps for zooplankters which cannot be broken down into smaller units. Finally, I will ask the question where in the evolution of these animals these units developed and became fused.

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**MS14**

**Coherence Resonance in Extended Systems**

First the phenomenon of coherence resonance is explained for a single excitable system subjected only to noise. Then it is demonstrated that this phenomenon also occurs in a heterogeneous chain of locally coupled Fitz Hugh-Nagumo neurons. Even more interesting, coherence resonance is enhanced due to the parameter heterogeneity of this extended system. Finally, we demonstrate that spatiotemporal coherence resonance also occurs in a diffusively coupled lattice of Roessler oscillators. Impacts of these findings in Neuroscience are discussed.

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**MS14**

**Coherence Resonance in Chaotic Systems**

It has been known that noise can enhance the temporal regularity of dynamical systems that exhibit a bursting behavior - the phenomenon of coherence resonance. But can the phenomenon be expected for non-bursting chaotic systems? We present a theoretical argument based on the idea of time-scale matching and provide experimental evidence with a chaotic electronic circuit for coherence resonance in non-bursting chaotic systems.

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**MS14**

**Coherence Resonance in Type I Stochastic Excitable Dynamics**

Type I excitable systems bifurcate from no firing to periodic firing via a saddle-node bifurcation. It is known that type II excitable systems such as the Fitzhugh-Nagumo system (which involves a Hopf bifurcation to the periodic firing state) as well as the integrate-and-fire model can exhibit coherence resonance in model studies. It is not known whether type I neurons, which are very common in the nervous system, exhibit this effect. We first study analytically the firing statistics (mean and variance of the first passage time, and the CV which is their ratio) for the normal form of such a type I neuron as a function of noise intensity and bias. We also show that the usual conversion of such dynamics to a phase representation introduces new effects due to the Stratonovich calculus. We find that the Ito interpretation produces coherence resonance, but not the Stratonovich interpretation. The relevance of these findings for synchronization of type I neurons to time varying inputs, as well as to type I bursting in neurons will be discussed.

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**MS14**

**Ghost Resonance in an Excitable Laser**

Abstract: We show both experimentally and numerically a ghost resonance in the sudden power dropouts exhibited by an excitable laser, in our case a semiconductor laser subject to optical feedback, driven by two simultaneous weak periodic signals. The small signal modulation conspires with the complex internal dynamics of the system to produce a resonance at a ghost frequency, i.e. a frequency that is not present in the driving signals.

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**MS14**

**System Size Coherence Resonance**

We show the existence of a system size coherence resonance effect for an ensemble of globally coupled excitable systems. Namely, we demonstrate numerically that the regularity in the signal emitted by an ensemble of globally coupled Fitzhugh-Nagumo systems, under excitation by independent noise sources, is optimal for a particular value of the number of coupled systems. This resonance is shown through several different dynamical measures: the time correlation function, correlation time and jitter.

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**MS15**

**Numerical Study of the Interaction Between Solitons and Radiation in Random Media**

An imperfect medium creates perturbed soliton which sheds radiations. Moreover, the interaction between solitons and radiation becomes noticeable as the propagation length increases. Thanks to some of the theoretical tools, analytical study of the nonlinear soliton interaction becomes accessible. However, due to the complicated nature of this phenomenon, it is necessary to associate the study with reliable physical experiments in order to justify the validity of the theoretical work. In the numerical study, it is ofeten observed that the shedding radiations by the disordered pulse cause fatal computational errors. In this presentation we provide a tool to overcome these numerical artifacts and compare its performance to the theoretical predictions.

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**MS15**

**Optical Fibers and Random Media**

In optical fiber systems, there has been interest in how certain parameters involving pulse propagation are affected by random dispersive effects. In this talk, we examine the behavior of a pulse under the influence of random dispersion via some parameters associated with the pulse (amplitude, width and chirp). We present some numerical and analytical results arising from the nonlinear Schrodinger equation with random dispersion.

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**MS15**

**Dynamics of Thermally Loaded Optical Parametric Oscillators**

Optical parametric oscillators (OPOs) are subject to environmental perturbations such as thermal loading which affect the refractive index of the nonlinear crystal. This heating induces spatial inhomogeneity, which interacts with the transverse structure of the signal and pump fields. We use renormalization techniques to reduce the interaction dynamics of these modes to a low-dimensional set of ordinary differential equations, which we use to investigate the impact of perturbed refractive index profiles on OPO dynamics.

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**MS15**

**Inter-channel Interactions Between Non-ideal Solitons**

We study the interaction between two solitons from distant frequency channels propagating in an optical fiber. The interaction may be viewed as an inelastic collision, in which energy is lost to continuous radiation due to non-zero third order dispersion. We develop a perturbation theory with two small parameters: the third order dispersion coefficient $d_3$, and the reciprocal of the inter-channel frequency difference $1/\beta$. We find that the leading contribution to radiation emitted during the collision is proportional to $d_3/\beta^2$, and the source term for this radiation is identical to the one produced by perturbation of the second order dispersion coefficient. The only other effects up to third order of the theory are shifts in phase and position. We propose a general recipe for using this perturbation method for studying soliton interactions under other forms of perturbations, and for studying interactions between non-ideal solitons of equations other than the nonlinear Schrödinger equation.

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**MS15**

**Short Pulses in Optical Fibers: A New Equation**

We derive a new equation describing the propagation of very short pulses in optical fibers. The new equation is derived directly from Maxwell's equations and takes into account both linear and nonlinear effects. The model is compared to the nonlinear Schroedinger equation that is usually used to model signal propagation in optical waveguides. Analytical results are compared to numerical solutions of full Maxwell's equations. This work is in collaboration with Gene Wayne.

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**MS16**

**Pulse Dynamics in Nonlinear Fiber Arrays**

When considering pulse propagation in optical systems, one is often led to the study of perturbed Hamiltonian systems where the perturbation is symmetry-breaking. In joint work with P. Kevrekidis and B. Sandstede we consider the eigenvalue problem for perturbed Hamiltonian systems. The analysis is accomplished via a Liapunov-Schmidt reduction, and is performed in such a way that we also get information on a global scale. The global information is achieved by computing the Krein signature of the perturbed eigenvalues, and by combining this calculation with previous results on reduced Hamiltonians. The theoretical results are quite general. We apply them to the study of pulse propagation in linearly coupled nonlinear fiber arrays.

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**MS16**

### Lyapunov Exponents and the Essential Spectrum of the Linearized Euler Equations

We prove that the essential spectrum of the operator obtained by linearization about a steady state of the Euler equations governing the motion of inviscid ideal fluid in dimension two is a solid vertical strip whose width is determined by the maximal Lyapunov-Oseledets exponent of the flow induced by the steady state.

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**MS16**

### Stability of Solitary Waves of the Green-Naghdi Equations

Abstract not available at time of publication.

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**MS16**

### Dispersive Effects in a Modified Kuramoto-Sivashinsky Equation

We study the limiting behavior of the Kuramoto-Sivashinsky/Korteweg-de Vries (KS/KdV) equation

$$u_t = -\beta_1 u_{xx} - \beta_2 u_{xxxx} - \delta u_{xxx} - uu_x.$$

We show that in the appropriate sense, the solutions of KS/KdV tend to the solutions of the standard Korteweg-de Vries equation

$$v_t = -\delta v_{xxx} - vv_x,$$

as $\delta \to \infty$. The proof relies, to a large extent, on precise estimates for oscillatory integrals that yield pointwise bounds on Green's functions.

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**MS16**

### Corners in Interface Propagation

We study existence and stability of interfaces in reaction-diffusion systems which are asymptotically planar. We distinguish between rigid and oscillatory interface propagation. The existence of corners is reduced to the travelling-wave equation for systems of viscous conservation laws or variants of the Kuramoto-Sivashinsky equation. Besides the classical Lax shocks, we find pulses with exponential and logarithmic tails, under- and overcompressive shocks. The corner typically but not always points in the direction opposite of propagation. For the existence and stability problem, we rely on a spatial dynamics formulation augmented by an appropriate equivariant parameterization for relative equilibria.

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**MS16**

### Regularity of Ground States for DMNLS

We consider a cubic Nonlinear Schrodinger equation with periodically varying dispersion coefficient as it arises in fiber-optics communication (dispersion managed NLS). For the case of zero residual dispersion, we show that the dispersive properties of the equation can be used to improve the regularity of the existing ground state solutions.

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**MS17**

### Algebraic Properties of Graphs and Network Synchronization

The analysis and design of networks draws from a long history, especially in the context of communications, transportation, or computer technology. The mathematical tools developed in those areas are grounded on graph-theoretical concepts, both combinatorial and algebraic, and are thus centered around static properties of the network. However, recent applications to new areas in physics and biology have prompted a reexamination of the effect of these properties on the dynamical processes which take place on the network. We will present results that exemplify the influence of algebraic and combinatorial graph measures on the collective behavior of interconnected dynamical systems. In particular, we will concentrate on the problem of synchronization of coupled oscillatory systems under quite generic conditions.

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**MS17**

### Synchronization in Small-World Networks with a Time-Varying Coupling

This work contributes to elucidate the relation between the network dynamics and graph theory. A new general method to determine global stability of complete synchronization in regular and small-world networks is developed. This method is based on the Lyapunov function approach. In this context the main step is to establish a bound on the total length of all paths passing by an edge on the network connection graph. In particular, the method is applied to the study of synchronization in small-world networks of chaotic cells with a time-dependent coupling. We propose the blinking model which consists of a ring of cells with constant 2k nearest-neighbor couplings and time-dependent on-off coupling between any other pair of cells. We prove rigorous bounds for the global stability of synchronization for such networks in the case where the on-off switching time is fast. The synchronization thresholds are explicitly linked with the average path length of the coupling graph

and with the probability of on-off shortcut switchings.

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### MS17

### General Stability Analysis of Coupled Dynamic Systems

We consider the dynamics in coupled identical systems. We present a general methodology by combining the master stability function and Gershgorin disc theory to yield constraints on the coupling strengths to ensure the stability of synchronized states. Known results in the literature are derived as special cases of the general method.

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### MS17

### Generalized Turing Patterns in Coupled Dynamical Systems

We study coupled dynamical systems where each system is coupled to P neighboring systems. In the Fourier space, the dynamics reduces to the evolution of independent Fourier modes. We derive an explicit relation between the Fourier modes and the coupling strengths. Using this relation, we demonstrate that generalized Turing patterns that emerge can be selected by appropriately choosing the coupling strengths. Both one dimensional and two dimensional lattices are considered.

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### MS17

### Ordering and Pattern Formation in On-off Intermittency Desynchronization of Homogeneous Chaos

Pattern formations and spontaneous orderings in systems of coupled chaotic oscillators are investigated. Particular attention is focused on the on-off intermittent state after desynchronization bifurcations from homogeneous chaos. It is shown that near the bifurcation point the desynchronous intermittent chaotic motion can be universally classified to three distinctive elements: homogeneous chaos; spatially ordered pattern determined by the unstable mode of of homogeneous chaos; and the size on-off intermitency of this given pattern. This picture can be used for understanding pattern formations from chaos when parameters are adjusted far from the bifurcation point.

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### MS17

### The Onset of Synchronism in Globally Coupled Ensembles of Chaotic and Periodic Oscillators

A general stability analysis is presented for the determination of the transition from incoherent to coherent behavior in an ensemble of globally coupled, heterogeneous, continuous-time dynamical systems. The formalism allows for the simultaneous presence of ensemble members exhibiting chaotic and periodic behavior, and, in a special case, yields the Kuramoto model for globally coupled periodic oscillators described by a phase. Numerical experiments using different types of ensembles of Lorenz equations with a distribution of parameters are presented.

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### MS18

### Infimum of Entropy for Hyperbolic Attractors

We study the variation of the metric entropy with respect to the SRB measure in an extended open neighborhood of a given hyperbolic attractor. It is known that this entropy varies differentiably in terms of the attractor and the derivative formula can be calculated explicitly. We show that while the topological structure of orbits does not change for attractor s in this open neighborhood, the infimum of the entropy is zero.

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### MS18

### On the Ergodicity of Weyl Cocycles

Consider the skew-shift $T(x,y) = (x+\alpha, x+y)$ on the 2-torus, where $\alpha$ is irrational. Consider the cocycle $(x,y) \rightarrow e^{iy}$ from the 2-torus to the additive group of complex numbers. Form the skew-product map $\hat{T}(x,y,z) = (x+\alpha, x+y, z+e^{iy})$. A. Forrest proved that if $\alpha$ is sufficiently rapidly approximable by rationals then $\hat{T}$ is point transitive and conjectured existence of $\alpha$'s for which $\hat{T}$ is ergodic. We construct irrationals for which this conjecture is true. The proof is based on a certain estimate of Hardy and Littlewood.

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### MS18

### Statistical Properties of Equivariant Dynamical Systems

We present results on the statistical properties of compact

group extensions of dynamical systems with some degree of hyperbolicity. First we consider the question of ergodicity and mixing of such extensions. This is joint work with Andrew Scott. Next we consider statistical limit theorems for equivariant observations on compact group extensions of a wide class of base dynamics. In particular we consider the central limit theorem, weak invariance principle, law of the iterated logarithm and exponential decay of correlations. This is joint work with Ian Melbourne. Examples considered include compact group extensions of piecewise uniformly expanding maps (for example Lasota-Yorke maps) as well as systems that are nonuniformly expanding or nonuniformly hyperbolic.

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**MS18**

**Topological Transitivity of Extensions of Anosov Diffeomorphisms with Non-compact Fiber**

We show necessary and sufficient conditions for topological transitivity of $\mathbf{R}^n$ extensions of Anosov diffeomorphisms on infranilmanifolds. In particular, if the fiber is $\mathbf{R}$, the existence of a semi-orbit with the projection on $\mathbf{R}$ unbounded from above and from below is equivalent to topological transitivity. This is joint work with M. Pollicott.

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**MS18**

**Stable Ergodicity of Smooth Compact Group Extensions of Hyperbolic Set**

We obtain sharp results for the genericity and stability of transitivity, ergodicity and mixing for compact connected Lie group extensions over the basic set of a diffeomorphism. In contrast to previous work, our results hold for general hyperbolic basic sets, and are valid in the $C^r$-class. We also obtain results on stability of mixing for hyperbolic suspension flows and Axiom A flows, and generalize a result of Niţică and Pollicott about stably transitive $\mathbf{R}^m$-extensions.

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**MS18**

**Intermittency Near Bifurcations in Deterministic and Randomly Perturbed Systems**

In families of dynamical systems, intermittency can occur near bifurcations, such as saddle-nodes and boundary crises. In these bifurcations a periodic orbit or a small strange attractor, disappears to give rise to large, possibly chaotic bursts. Asymptotic formulae for the frequency with which orbits visit the regions previously occupied by the attractorwere derived heuristically in the 80's and have been widely used in applied dynamics. These formulae were recently proven for families of one dimensional maps by the authors. In the current work we describe intermittency in randomly perturbated version of one dimensional maps. We show that invariant measures for the perturbed systems converge weakly to appropriately chosen invariant measure for the unperturbed systems. This allows us to give rigorous formulae for intermittency in the randomly perturbed systems.

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**MS19**

**The Geometry and Dynamics of Generalized Double Bracket Equations**

In this talk I will discuss the geometry and dynamics of generalized double bracket flows – these are gradient flows on orbits of groups with respect to various invariant functions. The flows exhibit multiple equilibria which are related to the structure of the orbits. In particular we consider the stability basins of the equilibria and the relationship of the dynamics to the geometry of the moment map. I will also consider optimality of flows with respect to different norms. This is joint work with Arieh Iserles.

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**MS19**

**Dynamics on SU(n) and Adaptive Optics**

In recent work with Eric Justh, Mikhail Vorontsov and other colleagues, we have explored the problem of modeling via (gradient) dynamical systems the process of correcting wave front errors in optical systems caused by atmospheric turbulence. Other authors have shown that in the setting wherein diffraction effects are also to be taken into account, certain alternating projection algorithms can be viewed as searching for optimal elements of SU(n) to correct the wavefront errors. In this talk we will attempt to work out some further dynamical aspects arising from

this point of view. This is joint work with Eric Justh.

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**MS19**

**Reduction of Hamilton's Phase Space Principle**

In the theory of Lagrangian reduction for holonomic mechanical dynamic systems, one usually starts with Hamilton's *configuration space* principle. In this work we show that a similar procedure can be done with Hamilton's *phase space principle.* This results, in particular, in a variational principle for the Lie-Poisson equations and more generally for the Hamilton-Poincaré equations. As with the Euler-Poincaré equations, there are constraints on the variations in the reduced variational principle. Speculations on the analog of this for nonholonomic systems will be entertained. Based on joint work with Hernan Cendra, Sergey Pekarsky and Tudor Ratiu.

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**MS19**

**Integrable Particle Interactions on Curves and Surfaces**

When a system of N-interacting particles is constrained to move on a closed curve in 1D or a compact surface in 2D, there is a complex interplay between the underlying dynamics determined by the governing Hamiltonian and the geometric properties of the curve or surface. In this talk, I will formulate the general equations for N-interacting particles constrained to lie on a planar curve, then describe in detail the case with logarithmic (point vortex) interactions. Surprisingly, when the closed curve is circular, the system is completely integrable for all N, in contrast to the 2D spherical problem which is integrable for N ¡ 4.

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**MS19**

**Bifurcations of Hamiltonian Relative Equilibria**

We still do not fully understand even 'typical' bifurcations of relative equilibria of Hamiltonian systems with symmetries. In the past year or two a number of different approaches have been proposed by several authors. In this talk I will attempt to give an overview, illustrate the results with some model systems (including molecules and coupled rigid bodies), and describe where the remaining problems lie.

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**MS19**

**Momentum Conservation in Nonholonomic Mechanics**

In nonholonomic mechanics, symmetries do not always lead to conservation laws as in the classical Noether theorem. Instead, the momentum of a generic nonholonomic system satisfies a dynamic momentum equation. This momentum equation can in some situations produce non-obvious conservation laws. In this talk, we give an overview of the structure of the momentum equation and discuss conditions that imply conservation of some of the components of the nonholonomic momentum.

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**MS20**

**Reduced-order Analysis of the Compressible Turbulent Jet**

The proper orthogonal (or Karhunen-Loève) decomposition (POD) extracts the most energetic features of a random field. The decomposition is applied to a simulation database of the compressible turbulent jet (Freund, *J. Fluid Mech.*, vol. 438, 2001), revealing the most energetic features of the near field of the jet. The compressible turbulent jet models such flows as the exhaust from a jet engine, and energetic structures in the flow are thought to contribute significantly to the noise produced by the jet. Here, reduced-order analysis will be used primarily as a diagnostic tool through the identification of flow features that contribute significantly to the structure and properties of the jet. In addition, the time-dependent flow field will be reconstructed using a small set of basis functions identified by the POD.

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**MS20**

**Multi-Scale Analysis of a Jet Flow Using POD**

We construct a reduced basis via proper orthogonal decomposition (POD) of a jet flow in order to give an approximation of far field noise radiation resulting from changes in input parameters (tabs, lobes, etc.). Traditional use of POD produces a reduced basis that optimally approximates a given field with respect to a certain metric (norm). In the context of jet flows, we are interested in multi-scale flow phenomena where a single metric may not be adequate to describe all aspects of the flow. In particular, the energy of the radiated noise is several orders of magnitude smaller than the turbulent kinetic energy (TKE, or $L_2$ energy) of the flow. Similarly, the energy that tabs or lobes introduce to the flow is by necessity (due to efficiency requirements) much smaller than the TKE. In the present study, we are interested in constructing a reduced basis that simultaneously approximates these different features of the flow. The

POD analysis is done on data from a vortex-method simulation of a jet flow. We use a number of different metrics ($L_2$, $H^1$, vorticity, and others) and compare their efficiencies in terms of approximating both the TKE of the flow and the far-field radiated noise computed from the Powell source.

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## MS20

### Error, Sensitivity, and Computational Complexity of POD

For the POD method we provide an analysis of errors involved in solving an initial value problem. We also look at the effects of perturbation of POD data on the reduced order model, and its solution trajectories. We present some interesting examples to illustrate situations where POD method could give very wrong results. We also present a study of the computational savings in using a POD reduced model for solution of initial value problems

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## MS20

### Links Between POD and Balanced Truncation

We elucidate some connections between two popular methods of model reduction: balanced truncation and Proper Orthogonal Decomposition (POD)/Galerkin projection. We show that ideas from balanced truncation may be used to select a suitable norm for POD, and this norm heavily weights states of large dynamical importance, even though these states may have small overall energy. The method scales well to large systems, and we illustrate this by applying it to a channel flow.

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## MS20

### Models for Turbulent Plane Couette Flow Using the Proper Orthogonal Decomposition

We model turbulent plane Couette flow for a Minimal Flow Unit (the smallest domain in which turbulence can be sustained) by expanding the velocity field as a sum of optimal modes calculated via the Proper Orthogonal Decomposition from numerical data. Ordinary differential equations are obtained by Galerkin projection of the Navier-Stokes equations onto these modes. We exhibit a model which provides empirical evidence that the "backbone" for Minimal Flow Unit turbulence is a periodic orbit.

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## MS20

### Archetypal Dynamics of Cellular Flames

The application of archetypal analysis to high-dimensional data arising from video-taped images of cellular flames is presented. A hybrid principal components/archetypes technique has been developed to overcome the difficulties of applying archetypes to data sets with points living in a space of dimension higher than about 500. The advantages of the method lie in the creation of patterns typical of the set as a whole, and an expression of the dynamics in terms of these patterns. Archetypes are particularly useful identifying intermittent regimes, where low energy events that might be missed by a severe principal component truncation are none-the-less crucial to understanding the dynamics. They are part of a suite of data analysis techniques that can be used on dynamic data sets (FFT, PCA and other spectral decompositions) and this hybrid method extends the application of archetypes to spatio-temporal dynamics in two-dimensional patterns.

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## MS21

### Phase-Space Warping: A General Approach to Machinery Diagnosis and Prognosis

Abstract not available at time of publication.

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## MS21

### A Study of Measurement Noise in Chaotic Signals

We present a method of estimating the correlation dimension, correlation entropy, and noise amplitude in a time series containing Gaussian measurement noise. We use Gaussian kernel functions, extending Diks's work (1996) and Schreiber's (1993). The thoroughness of our estimates is comparable to that of Diks, through high noise amplitudes, but ours can be more efficient computationally. We compare our results with theirs, in model problems.

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## MS21

### Vibration-Based Damage Assessment Using Novel Function Statistics with Multiple Time Series

Analyis of data from experiments on dynamical systems often centers on the embedding of time series data to reconstruct an attractor. In our system, we consider output from (chaotic excitation of) a circuit designed to simulate a spring-mass system in both a damaged and an undamaged state. We employ a new version of the continuity statistic, first introduced by Pecora, Carroll and Heagy[1]. Here we use the statistic in the new setting of multiple time series embedding. We show the continuity statistic is an appropriate and sensitive tool for showing differences in the reconstructed attractors in the damaged and undamaged states. [1] Pecora, L.M., Carroll, T.L. and Heagy,

J.F. [1995] Statistics for mathematical properties between time-series embeddings, Physical Review E 52(4),3420.

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**MS21**

**Detecting Nonlinear Interactions in Biological Systems**

A rigorous analytical approach is developed to test for the existence of a continuous nonlinear functional relationship between systems. We compare the application of this nonlinear local technique to the existing analytical linear global approach in the setting of increasing additive noise. For natural systems with unknown levels of noise and nonlinearity, we propose a general framework for detecting coupling. Lastly, we demonstrate the applicability of this method to detect coupling between simultaneous experimentally measured intracellular voltages between neurons within a mammalian neuronal network.

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**MS21**

**Damage Detection and Localization Using a Steady-State Chaotic Dynamic Approach**

The utility of Chaotic Attractor Property Analysis (CAPA) is explored with regard to diagnosing the degree of joint degradation in an experimental structure. Data collected from a healthy structure are used to build empirical phase space models of the "healthy" dynamics. Using a simple attractor-based prediction scheme, data coming from a damaged structure are forecast using these baseline models. Prediction error is then introduced as a feature for diagnosing both the magnitude and location of damage.

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**MS21**

**Quantifying Wave Propagation Through a Composite Joint: Application to Structural Health Monitoring**

This work investigates the propagation of a chaotic waveform through a composite joint. A composite beam is bolted at each end to an aluminum plate. Fiber Bragg gratings are placed on both materials so that response data can be recorded on either side of the connection. The beam is interrogated using a chaotic signal resulting in a low-dimensional response from both the beam and plate. The mapping between attractors reconstructed from these data are used to explore how the dynamics change as the quality of the connection is degraded.

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**MS22**

**Atomistic/Continuum Simulation of Nano-Fluidics**

In this talk, I will present the latest development of atomistic/continuum hybrid method for simulating micro- and nano-fluid flows. The proposed numerical method is intended for modeling systems with multiple time and spatial scales. Numerical benchmark of the hybrid method, including comparison of the hybrid method with full molecular dynamics simulation, will be shown. Applications of the hybrid method for realistic engineering problems, including fluid flow in rough walls and multiphase surface contacts, will be discussed.

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**MS22**

**Turbulent Flows in Weighted Sobolev Spaces Using the Anisotropic Lagrangian Averaged Navier-Stokes Equations**

The anisotropic Lagrangian averaged Navier-Stokes equations have been developped by Marsden and Shkoller to model the anisotropy of the fluctuations of the covariance tensor for a turbulent flow in a domain with boundary. The degenaracy of this fluctuation along the boundary induces some degenerate elliptic operators in the model, requiring the introduction for the analysis of appropriate methods (in some weighted Sobolev spaces) that I will describe in this talk.

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**MS22**

**Lagrangian Averaged Navier-Stokes-alpha (LANS-alpha) Model for Turbulence**

The turbulence equation known as the LANS-alpha model was derived using Reynolds decomposition in Hamilton's principle, followed by Lagrangian averages and Taylor's hypothesis for frozen-in fluctuations at a linear level.

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**MS22**

**Numerical Simulations of Isotropic Homogeneous Turbulence Using the Lagrangian Averaged Navier Stokes-$\alpha$ Equations**

Capabilities for turbulence calculations of the Lagrangian averaged Navier-Stokes (LANS-$\alpha$) equations are investigated in decaying and statistically stationary three-

dimensional homogeneous and isotropic turbulence. Results of the LANS-$\alpha$ computations are analyzed by comparison with Direct Numerical Simulation (DNS) data and Large Eddy Simulations (LES). Implementation of a newly derived dynamic averaged Navier-Stokes-$\alpha$ equations will be reviewed and computational results will be presented.

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### MS22

### Variational Asymptotics for Rotating Fluids Near Geostrophy

In this talk I will demonstrate a variational asymptotic ansatz based for the shallow water equations—involving an infinitesimal change of coordinates in the low-Rossby number expansion of the variational principle –which can reproduce a number of known semi- and quasigeostrophic models as well as new ones. This formulation makes it easy distinguish models based on their analytical properties (their well-posedness and regularity) and choose those most consistent with the model setting: Vortical motion at large scales.

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### MS22

### Averaging and Filtering of Lagrangian Fluid Systems

The Lagrangian Averaged Navier Stokes (LANS-alpha) equations have traditionally been derived by averaging under the Lagrangian integral and using an extension of G.I. Taylor's frozen turbulence assumption as the turbulent closure hypothesis. In this talk we reconsider this derivation from the point of view of both the Reynolds decomposition and diffeomorphism decomposition of Marsden and Shkoller, separating out the averaging and modeling stages. Based on this we propose a number of new modeling assumptions and derive a number of equations for both averaged incompressible and compressible flow.

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### MS23

### Synchrony in Model Neurons in an Electric Field

Motivated by the observation that applied electric fields modulate hippocampal seizures, and that seizures may be asynchronous, we modeled synaptically-coupled 2-compartment hippocampal pyramidal neurons embedded within an electrically resistive lattice in order to examine network synchronization properties under the influence of externally applied electric fields. Excitatory electric fields were shown to synchronize or desynchronize the network depending on the natural frequency mismatch between the neurons. Such frequency mismatch was found to decrease as a function of increasing electric field amplitude. These findings provide testable hypotheses for future seizure control experiments.

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### MS23

### Loss of Rhythms in Neuronal Networks as a Result of Too Much Drive to the Inhibitory Cells

Synchronous rhythmic spiking in neuronal networks is often brought about by the interaction between E-cells and I-cells (excitatory and inhibitory cells): The I-cells gate and synchronize the E-cells, and the E-cells drive and synchronize the I-cells. Rhythms generated in this way are called PING (Pyramidal-Interneuronal Network Gamma) rhythms. The PING mechanism requires that the intrinsic firing frequency $\nu_I$ of the I-cells be sufficiently small. We examine how the rhythm is lost when $\nu_I$ gets too large, using a combination of analysis and numerical experiments for model networks of theta neurons. For a PING rhythm at a frequency far below the gamma range, even raising the value of $\nu_I$ very slightly above zero results in complete *suppression* of the E-cells, provided that the spiking of the I-cells is sufficiently far from synchronous. (Asynchronous spiking of the I-cells inhibits more effectively than synchronous spiking.) PING rhythms in this regime are therefore highly vulnerable to noisy external input driving and de-synchronizing the I-cells. By contrast, PING rhythms in the gamma frequency range are much more robust. In this parameter regime, the rhythm is lost not as a result of suppression of the E-cells, but as a result of *phase walkthrough* — $\nu_I$ becomes so large that the I-cells fire without being prompted by the E-cells. Roughly, this happens when $\nu_I$ comes close to the frequency of the PING rhythm. In summary, our findings justify the "G" in "PING": PING rhythms below gamma frequency are possible, but not robust.

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### MS23

### Subthreshold Oscillations and Resonance in Neurons

Many neurons can exhibit autonomous (intrinsically generated) damped or sustained subthreshold oscillations of membrane potential. The frequency range is usually between 10 and 50 Hz, but it can be as high as 200 Hz in some neurons. We use analytical and experimental approaches to reveal the function of such oscillations in the brain.

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**MS23**

**Temporal Coding Properties of Coupled Oscillator Neuron Models Exhibiting Synchrony**

Networks of coupled populations of neurons are ubiquitous in different neural systems, and the synchronous activity of such populations is a topic of active interest. The level of synchrony between neurons is dependent on the way they are coupled as well as the extent of connectivity across the network. This study looks at the ability of coupled networks of model neurons to reconstruct different random stimuli using linear reconstruction techniques. In particular we wish to determine how the type of synchronous behaviour the neurons exhibit (i.e. synchrony, anti-synchrony or asynchrony) is connected to relative changes in the quality of stimulus reconstruction. A combination of numerical simulation and analytic techniques are used to understand the phenomena in leaky integrate-and-fire neurons as well as phase oscillator models.

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**MS23**

**Random Dynamics and Entrainment to Synaptic Inputs**

Motivated by spike time reliability experiments, we study the entrainment of simple neural oscillators to periodic, white noise and more general forcings. We analyze a PDE governing time evolution of the phase probability density, with a simplifying approximate change of variables around spatial extrema. We find entrainment to broadband but not appropriately filtered inputs, describe temporal variation of spike time reliability in terms of transient deterministic effects, and connect the dynamics to experimentally observable variables.

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**MS23**

**Synchronized Rhythms and the Flow of Motor Information**

In Parkinson's disease (PD), the development of abnormal synchronized oscillations in the basal ganglia is believed to contribute to motor pathologies, such as tremor and difficulty initiating movements. We have previously explained how biological changes associated with PD may lead to these oscillations in a biophysical basal ganglia model. Now, we consider how synchronized oscillatory output from the basal ganglia affects the ability of its target area in the thalamus to relay motor inputs to the cortex. In general terms, we are asking how properties of an inhibitory input (including its degree of synchrony) affect the ability of excitable relaxation oscillators to become phase-locked to other, excitatory inputs. We are able to answer this question through simulations and examination of appropriate phase planes.

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**MS24**

**Dynamics and Stability of Deformable Rods**

This talk will treat the behavior of solutions of the geometrically exact equations for the motion of deformable rods in space. These rods can suffer not only flexure and torsion, but also shear and both longitudinal and transverse extension. Special attention will be devoted to describing the qualitative distinctions between compressible and incompressible rods.

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**MS24**

**Localized Waves in Elastic Rods: Existence and Stability**

Localized waves in one-dimensional structures can carry deformation, information, or energy. These waves are important in many different processes such as the twisting and untwisting of DNA molecules, the problem of prey detection and localization in spider webs, the motility of flagellar microorganisms and the alleged whipping of dinosaur tails. In this talk, I will review and study the propagation of (mostly localized) waves in one-dimensional elastic structures from a theoretical standpoint. I will show exact and approximate traveling waves solutions and study their domain of existence and stability. Finally, if time permits, I will consider the propagation and acceleration of localized waves in nonhomogeneous media.

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**MS24**

**The Mechanics of Multi-stranded Plies : Applications to Fibrous Proteins**

We study the mechanics of uniform n-plies, correcting and extending previous work in the literature. An n-ply is the structure formed when n pretwisted strands coil around one another in helical fashion. Such structures are encountered widely in engineering (mooring ropes, power lines) and biology (DNA, proteins). We first show that the well-known lock-up phenomenon for n=2, described by a pitchfork bifurcation, gets unfolded for higher n. Geometrically, n-plies with n¿2 are all found to behave qualitatively the same. Next, using elastic rod theory, we consider the mechanics of n-plies, allowing for axial end forces and end moments while ignoring friction. An exact expression for the interstrand pressure force is derived, which is used to

investigate the onset of strand separation in plied structures. After defining suitable displacements we also give an alternative variational formulation and derive (nonlinear) constitutive relationships for torsion and extension (including their coupling) of the overall ply. For a realistic loading problem in which the ends are not free to rotate one needs to consider the topological conservation law, and we show how the concepts of link and writhe can be extended to n-plies.

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**MS24**

**Bifurcation of Compressed Hemitropic Rods**

Chiral rods are modelled using a Special Cosserat theory, characterized by transverse hemitropy, viz., the maximal symmetry group at each cross section is $SO(2)$. A spatial Cosserat theory will be presented for large buckling problems with clamped-free and clamped-clamped ends. While (surprisingly) the clamped-free ends admit only planar buckling, clamped-clamped ends yield only nonplanar buckled solutions. Nontrivial solutions are rigorously shown to exist for a wide class of constitutive behaviors, and are seen to be direct extensions of the two dimensional Euler Buckling theory for clamped ends.

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**MS25**

**A New 0-1 Test for Chaos**

We describe a new test for determining whether a given deterministic dynamical system is chaotic or nonchaotic. In contrast to the usual method of computing the maximal Lyapunov exponent, our method is applied directly to the time series data and does not require phase space reconstruction. Moreover, the dimension of the dynamical system and the form of the underlying equations is irrelevant. The input is the time series data and the output is 0 or 1 depending on whether the dynamics is non-chaotic or chaotic. The test is universally applicable to any deterministic dynamical system, in particular to ordinary and partial differential equations, and to maps. Our diagnostic is the real valued function $p(t) = \int_0^t \phi(\mathbf{x}(s)) \cos(\theta(s)) r ds$ where $\phi$ is an observable on the underlying dynamics $\mathbf{x}(t)$ and $\theta(t) = ct + \int_0^t \phi(\mathbf{x}(s)) r ds$. The constant $c > 0$ is fixed arbitrarily. We define the mean-square-displacement $\mathbf{M}(t)$ for $p(t)$ and set $K = \lim_{t\to\infty} \log \mathbf{M}(t)/\log t$. Using recent developments in ergodic theory, we argue that typically $K = 0$ signifying nonchaotic dynamics or $K = 1$ signifying chaotic dynamics.

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**MS25**

**Data Analysis in Big Dynamical Systems: Applications to Weather Forecasting**

This talk describes some aspects of a data assimilation technique that may provide better estimates than current methods of the relevant initial conditions for weather forecast models. The method attempts to take advantage of the frequent, relatively low local dimensionality of the dynamics of metereological models to reduce the computational burden. Preliminary results from recent versions of a global forecast model will be discussed.

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**MS25**

**Indistinguishable States: What is "Uncertainty in the Initial Condition" Really?**

Given a perfect model of a chaotic dynamical system, uncertainty in the initial condition forces us into probability forecasts even when the system is deterministic. The theory of indistinguishable states (Judd and Smith, 2001 Physica D , 151) guides the construction of ensemble forecasts which will allow accountable probability forecasts. When the model is imperfect, any attempt at forecasting will suffer both from model inadequacy and observational uncertainty. This is, of course, the case for all physical systems. The implications this holds for modelling dynamical systems is discussed in three contexts: laboratory experiments, operational weather forecasting, and climate modelling. In each case, there is no well-defined 'true' initial condition in the model's state space; model inadequacy prevents accountable probability forecasts in a manner analogous to the way that chaos prevents accurate forecasts in a root-mean-square sense. It is shown that even if the true system is deterministic, the model should almost certainly include dynamical noise. Several approaches for the construction of such models and the implications these results hold for nonlinear models in general, are discussed.

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**MS25**

**Learning About Reality From Observation**

(See www.math.umd.edu/ ott for a copy of the paper written with Will Ott ,Univ. of Maryland.) 2400 years ago Plato asked what we can learn from seeing only shadowy images of reality. In the 1930's Whitney studied "typical" images of manifolds in $R^m$ and asked when the image was

homeomorphic to the original. Let $A$ be a closed set in $R^n$ and let $\phi : R^n to R^m be$ a "typical" smooth map where $n > m$. (Plato considered only the case $n = 3, m = 2$). Whitney's question has natural extensions. If $\phi(A)$ is a bounded set, can we conclude the same about A? When can we conclude the two sets have the same cardinality or the same dimension (for typical phia)? (To simplify or clarify those questions, you might assume phi is a "typical" linear map in the sense of Lebesgue measure.) In the 1980's Takens, Ruelle, Eckmann, Sano and Sawada extended this investigation to the typical images of attractors of dynamical systems. They asked when typical images are similar to the original. Now assume further that $A$ is a compact invariant set for a map $f$ on $R^n$. When can we say that $A$ and $\phi(A)$ are similar, based only on knowledge of the images in $R^m$ of trajectories in $A$? For example, under what conditions on $\phi(A)$ (and the induced dynamics thereon) are $A$ and $\phi(A)$ homeomorphic? Are their Lyapunov exponents the same? Or, more precisely, which of their Lyapunov exponents are the same? This talk (and corresponding paper) addresses these questions with respect to both the general class of smooth mappings $\phi$ and the subclass of delay coordinate mappings.

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### MS26

### Hamiltonian Homoclinic Dynamics and Symplectic Topology

We present some results in the study of Hamiltonian dynamics in a neighborhood of homoclinic orbits to different type of equilibria, periodic orbits and invariant Diophantine tori and demonstrate how these investigations lead to some problems in symplectic topology. The latters appear first when we try to transform the system locally near the basic invariant set (equilibrium, periodic orbit or invariant torus) into some convenient form in order to understand the behavior of the system near this set. The another source is the features of the global behavior of the system under consideration when one studies the global dynamics near a homoclinic orbit.

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### MS26

### Control of Hamiltonian Systems with Integrable Nominal Dynamics

We present approaches to control of hamiltonian systems with integrable nominal dyamics (i.e. the system is integrable when it is not affected by control forces). A prototypical case is that of a twist map and this case is studied in detail. It is shown under mild conditions that an arbitrarily small non-dissipative control (i.e. aperiodically time-dependent) perturbation to an integrable twist map renders the system controllable (i.e. any point in th phase space can be reached from any other under a suitable sequence of perturbations). This is in sharp contrast with the statement of the Kolmogorov-Arnold-Moser theorem for the case of steady perturbations.

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### MS26

### On the Break-up of Shearless Invariant Tori in the Standard Nontwist Map

Many physical systems, such as magnetic field lines and particle orbits in plasma devices and tracer dynamics in fluid experiments, can be described by symplectic (area preserving) maps that violate the twist condition. Recent results on the break-up of shearless invariant tori in the standard nontwist map [e.g. del-Castillo, Greene, and Morrison, Physica D, 91, 1 (1996)] will be discussed and interpreted in the context of renormalization.

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### MS26

### Bailout Embeddings, Targetting KAM Tori and Hamiltonian Blow-out Bifurcations

The technique of bailout embedding, that allows to target orbits having particular properties out of all orbits in a flow or map is reviewed. In particular by explicitly constructing a bailout embedding for Hamiltonian systems, the targetting KAM tori by direct iteration is shown. The ability of the bailout dynamics to lock onto extremely small regular islands in a chaotic sea is demonstrated with a variety of examples.

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### MS27

### Feedback Control of Morphological Instabilities

A possibility of feedback control of morphological instabilities in directional solidification is investigated. Two ways of the feedback control are considered: (1) a local control by means of external heating within the melt and (2) a global control by adjusting the applied temperature gradient and the pulling speed. A special attention is paid to the case of small segregation coefficient, where the nonlinear instability is subcritical. The development and the suppression of instabilities are studied analytically and simulated numerically.

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### MS27

### Nonclassical Traveling Wave Solutions: Coupling Motion by Mean Curvature with Surface Diffusion

We study the coupled motion of an external surface moving motion by surface diffusion and a grain boundary moving by motion by mean curvature in the context of a bicrystalline specimen where one crystal is growing at the expense of another. We demonstrate the existence of traveling wave solutions for all physically viable parameter values, and show that the profiles obtained are not always describable via the graphs of functions.

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### MS27

### Faceting and Roughening of a Growing Crystal Surface by Surface-Diffusion Mechanism

Faceting of a crystal surface caused by strongly anisotropic surface-tension, driven by surface diffusion and accompanied by deposition (etching) due to fluxes normal to the surface is considered. Nonlinear evolution equations for 1+1 and 2+1 crystal surfaces are solved analytically and numerically. It is found that with the increase of the growth rate the faceting dynamics exhibits transitions from the power-law coarsening to fixed-size pyramidal structures and finally to spatio-temporally chaotic surfaces resembling kinetic roughening.

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### MS27

### The Coarsening Dynamics of Faceted Crystal Surfaces

The *faceting-Cahn-Hilliard* ($\mathcal{FCH}$) equation governs the *annealing* of a faceted crystal surface when *attachment kinetics* is the dominant mass transfer mechanism. The *Hamilton-Jacobi-Cahn-Hilliard* ($\mathcal{HJCH}$) equation is the associated growth model:

$$h_t - \varepsilon\hat{\mathcal{F}}(\nabla h) = \mathbf{div}\left[D\hat{\mathbf{W}}\left(\nabla h\right)\right] - \Delta^2 h. \qquad (1)$$

We identify the sharp-interface theories for both ($\mathcal{FCH}$), $\varepsilon = 0$, and ($\mathcal{FECH}$), $0 < \varepsilon \ll 1$, through a matched asymptotic analysis. The result is a novel edge-network dynamical system ($\mathcal{ENDS}$). Coarsening occurs through the merging and annihilation of facets. Our theory characterizes both the *coarsening exponents* and surface morphologies, and naturally extends to a broad class of faceted crystal growth problems.

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### MS28

### A Geometric Theory of Chaotic Phase Synchronization

We extend geometric results on synchronization in driven periodic oscillators to a class of phase coherent chaotic systems, producing reduced equations describing the dynamics of the phase difference between the drive and response. The equations illustrate the importance of the structure of the attractor in the system's response to perturbation and indicate that, in this context, chaotic phase coherent systems may not always be treated as noisy periodic oscillators.

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### MS28

### Competition Between Two Signals for Phase Synchronism of a Chaotic Process

We discuss the situation where two periodic signals compete to phase synchronize a chaotic attractor. Depending on the relative position of the periods with respect to the synchronization tongue for a single frequency signal, we distinguish several different cases. We find that, depending on parameters, it is possible that one or the other signal will entrain exclusively, or that they will entrain alternately, at their average frequency, or not at all.

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### MS28
### Noise-induced Phase Synchronization

This contribution presents recent results on constructive effects of noise to synchronization of chaotic oscillators. First the mechanism of complete synchronization induced by common unbiased noise is clarified. Second the phenomenon of noise induced-phase synchronization is discussed for several paradigmatic model systems. Finally experimental results on on noise-enhanced phase synchronization are given.

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### MS28
### Phase Synchronization in Convective Experiments

We present experimental phase synchronization states in a Benard-Marangoni cell in a regime of time dependent chaotic convection. A peltier element inserted in the heater allows one to drive the system with an external periodic modulation, that induces the appearance of a phase synchronized state, wherein thermal plumes formed in the thermal boundary layer are reinjected there, after being dragged by the main convective flow. We provide an exaustive characterization of this dynamical regime.

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### MS29
### Phase Transitions, Coarsening and Patterns and Electrostatically Drivengranular Media

Large ensembles of small particles display fascinating collective behavior when they acquire an electric charge and respond to competing long-range electromagnetic and short-range contact forces. Many industrial technologies face the challenge of assembling and separating such single- or multi-component micro and nano- size ensembles. ¡?xml:namespace prefix = o ns = "urn:schemas-microsoft-com:office:office" /¿ We studied the dynamics of conducting microparticles in strong electric field in the air or in deep vacuum. Phase transitions and clustering instability of the electrostatically driven granular gas were found. A continuum model for the phase separation and coarsening in was formulated in terms of a Ginzburg-Landau equation subject to conservation of the total number of grains. In the regime of well-developed clusters, the continuum model is used to derive "sharp-interface" equations that govern the dynamics of the inter-phase boundary. The situation is remarkably different when the cell filled with poorly conducting liquid (toluene-ethanol mixute). We have found that metallic particles form a rich variety of phases not observed in air-filled cell. These phases include static precipitates: honeycombs lattices and Wigner crystals; and novel dynamic condensates: toroidal vortices and pulsating rings. The observed phenomena are attributed to interaction between particles and electro-hydrodynamic flows produced by the action of the electric field on ionic charges in the bulk of liquid.

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### MS29
### Granular Shear Flow: Memory in Sand

Granular matter such as sand can sustain stresses like a solid, or flow like a fluid. Flow transients in particular are complex and often defy description as solid-like or fluid-like. We experimentally investigate one examples of such unique granular properties: The motion of particles and the shear forces at the start of a shear flow depend on both the direction of prior shear and on the time since the material was last sheared. We investigate the characteristic lengthscales and timescales of of these flow transients with high speeed imaging. To understand how memory effects can arise in a packing of hard spheres we use confocal microscopy, which captures rearrangements of individual particles in the interior of the granular material.

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### MS29
### Coarse-Grained Stability and Bifurcation Analysis of Granular Flows

Systematic derivation of macroscopic equations for granular flows is difficult because strong long-range correlations do not allow accurate mean-field approximations. Further, an important granular property, surface roughness, has not yet been successfully incorporated in continuum descriptions of granular systems. Assuming no knowledge of macroscopic continuum equations, we implement a coarse-timestepper based approach [Theodoropoulos *et al.*, PNAS, **97**, 9840 (2000)], wrapped around a molecular dynamics simulator [Bizon *et al.* PRL, **80**, 57 (1998)], to examine the coarse stability/bifurcation of oscillating granular layers.

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### MS29
### Shear Instabilities in Granular Flows

Unstable waves have long been studied in fluid shear layers. These waves affect transport in the atmosphere and oceans as well as slipstream stability behind ships, planes, and heat transfer devices. Corresponding instabilities in granular flows have not previously been documented, despite the importance of these flows in geophysical and industrial systems. We report here that breaking waves can form at the interface between two streams of identical grains downstream of a splitter plate. These waves appear abruptly in flow down an inclined plane as either shear rate or angle of incline is changed, and we analyze a granular flow model that qualitatively agrees with our experimental data. The waves appear from the model to be a manifestation of a competition between shear and extensional strains in the flowing granular bed, and we propose a dimensionless group to govern the transition between steady and wavy flows.

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### MS30
### User Interface Design Patterns for Interactive Modeling with Python

The presentation is focused on the user interface design (UID) patterns for interactive modeling. Main objectives were to develop the UID patterns to increase the usability of the software for numerical computing and to make the process of numerical simulation highly interactive. On the basis of these UID patterns authors developed reusable software components using Python programming language and PyQwt scientific plotting library. The presentation describes UID patters for analysis, visualization and simulation of data: Two-Panel Selector, Interactive 2D Input, and Multiple Observer with States. The Two-Panel selector applicable to the design of systems for interactive analysis of data, when the user has to select subsets of data. Frequently this selection is made on the basis of user knowledge and the development of selection algorithms may be an extremely complex task, because rules on which the formalization could be made are hard to articulate. The 2D Interactive Input Pattern found its usage in the software for optimization of non-parametric or semi-parametric models. A determination of an initial guess usually requires significant amount of time. Instead of guessing and trying different inputs coded in functional or tabular forms, the user may simply draw the initial guess by the mouse so that it will be close to the values of the empirical data. The Multiple Observer with States allows the user to easily accumulate displays of heterogeneous data. Usage of this pattern improves the performance time and user's satisfaction. The patterns described were verified in the development of practical software tools for demographers and biostatisticians, but can be readily applicable to other domains of numerical computing. The presentation includes an interactive demonstration of the software for non-parametric optimization written in Python.

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### MS30
### Agent Based Modelling of HIV Evolution

The majority of models of HIV transmission, both within and between hosts, are population-based models described using systems of differential equations. Individual- or agent-based models (ABMs) offer an attractive alternative approach. The clean object-oriented design of Python, and the ability to implement lightweight threads facilitates the rapid construction of ABMs comprising of many agents. I will discuss two examples. The first example considers the spread of drug-resistant HIV within a community. An agent based approach allows the complex distributions of passage times within model compartments (susceptible, infected, treated, etc.) to be modeled with ease. The second example considers the evolution of HIV within an infected individual, where each infected cell is a separate agent. This permits the simultaneous modeling of viral dynamics and viral evolution, which occur on similar timescales in viruses such as HIV and hepatitis C. It is also straightforward to perform batch runs of these models in parallel, allowing large areas of parameter space to be explored rapidly.

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### MS30
### Development of an Integrated, Multidisciplinary Water Quality Model Using Python

A model for predictions for water quality of post mining lakes was developed. It includes ground and surface water interaction, erosion, transport as well as chemical and biological processes. Python was used as the primary programming language to integrate three existing, numerical models and newly developed modules into a comprehensive model. The use of Python greatly facilitated the application of object-oriented programming, design patterns, distributed computing, hybrid programming, object persistence, testing, cross-platform development, and 3D-visualisation.

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**MS30**

**Open Discussion of Future Evolution of Python**

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**MS31**

**Vortex Lattices in Bose-Einstein Condensates**

We employ molecular dynamical (MD) techniques based on pair potentials to study the dynamics of vortex clusters. The MD description allows to incorporate the external potentials and kinetic dissipation necessary for the relaxation of the vortex gas to the ground state configuration. The results obtained by the MD technique are compared to full numerical simulations of the Gross-Pitaevskii equation.

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**MS31**

**Instability of Local Deformations of an Elastic Rod**

We study the instability of pulse solutions of two coupled nonlinear Klein-Gordon equations by means of Evans function techniques. The system of coupled Klein-Gordon equations considered here describes the near-threshold dynamics of a three-dimensional elastic rod with circular cross-section, subject to constant twist. We determine a condition on the speed of the traveling pulse which ensures spectral instability.

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**MS31**

**Spectral Stability of Localized Vortices for Nonlinear Schrödinger Equations**

Nonlinear Schrödinger equations in 2+1 dimensions admit non-radial standing waves with vortex symmetry that carry nonzero intrisic angular momentum. For nonlinearities of *focusing-defocusing* type, such as cubic-quintic, we provide evidence that some of these spinning solitary waves are spectrally stable. For the evolution equations linearized around a localized spinning wave, we prove that unstable eigenvalues are zeros of an Evans function for one of a finite set of ordinary differential equations. Numerical computations indicate that there exist spectrally stable standing waves having central vortex of any degree. These exist in a regime where the wave structure has a vortex core, 'encapsulated' by a weakly curved membrane or 'kink' which localizes the wave. I will also discuss recent progress adapting our techniques to treat vortices in Bose-Einstein condensates.

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**MS31**

**Evans Function Analysis of Stationary Light Transmission in Nonlinear Photonic Structures**

We study optical bistability in nonlinear periodic structures of finite and semi-infinite length. For finite-length structures, the system exhibits instability mechanisms typical for dissipative dynamical systems like delay-differential equations. We show that the Leray-Schauder degree equals the sign of the Evans function in the origin. Using the Evans function methods, we rigorously prove that the stationary solutions with optically bistable transmission characteristics are indeed spectrally unstable. For semi-infinite structures, the system may have at most two stationary pulse solutions: one of which is monotonic and the other one has a single maximum. We show that the non-monotonic pulse solution is always spectrally unstable. A new unstable eigenvalue bifurcates in the spectrum of stationary pulse solutions near the turning point, when the pulse maximum occurs at the end of the semi-infinite interval. We develop the normal form analysis and derive a one-dimensional dynamical system for bifurcations of stationary pulse solutions near the turning point.

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**MS32**

**Discrete Approximations with Additional Conserved Quantities: Deterministic and Statistical Behavior**

Discrete numerical approximations with additional conserved quantities are important in studies of statistical behavior. As such, the sine-bracket truncation with many conserved quantities can be used as a suitable approximation to 2D incompressible flow over topography. Here we

address the issues of statistical significance of additional conserved quantities beyond that of energy and enstrophy.

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## MS32

### Attractors of the Driven-damped, Spectral-truncated Burgers Equation

We study the dynamics of driven-damped Fourier-truncated Burgers equations and discuss various dynamic limits characterized by different power spectra. Asymptotic analysis of these limits will be presented. We also address the difference of empirical equilibrium states described by the maximum entropy principle and the Gibbs invariant measure captured by our asymptotic analysis. Finally we address the issue of dynamical predictability in the truncated Burgers equation and other spatially extended systems.

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## MS32

### Statistical Description of a Spectral Truncation of the Burgers-Hopf Equation

Recently, A. Majda and I. Timofeyev have introduced the Truncated Burgers-Hopf Equation as a prototypical test case for statistical mechanics. The talk will review the remarkable properties of this system, such as energy equipartition for a majority of randomly-chosen initial conditions, and correlation scaling that conforms with a simple dimensional argument. In addition, the newly-discovered Hamiltonian structure of the problem will be discussed. The relevance of the cubic Hamiltonian for the energy spectrum will be described within a statistical framework that includes both direct numerical simulations of the equation and a purely geometric Monte-Carlo computation.

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## MS32

### Equilibrium Statistical Mechanics for Spectral Truncations of Conservative PDE's

Aplication of the maximum entropy principle will be discussed for the spectral truncations of the conservative systems with quadratic integrals of motion in the context of the spectral truncation of the inviscid Burgers-Hopf equation and the 2D fluid flow over topography. The equilibrium statistical mechanics predictions for the long-term behavior of the solutions are then compared with the direct numerical simulations. The effects of the higher conserved quantities and the symmetry breaking bifurcations are also addressed.

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## MS33

### A Mechanism for High-Pass Filtering of Neuronal Signals

Synaptic plasticity can be viewed as a means for filtering neuronal signals. Synaptic depression and various forms of facilitation due to plasticity in the transmitter release mechanism are well-known sources of short-term plasticity. Another form of plasticity has been the focus of a great deal of experimental work over the past few years. This involves receptor-induced activation of G-proteins in the presynaptic terminal, which regulate calcium channels and thus the release of neurotransmitters. The mechanism of G-protein regulation of transmitter release will be discussed, and it will be demonstrated that this mechanism can act as a high-pass filter of information in a neuronal circuit.

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## MS33

### Phase Maintenance in Neuronal Networks

In many physiological settings, neurons are capable of maintaining phase relationships despite large changes in network frequency. Using techniques of geometric singular perturbation theory, we show how short-term synaptic depression acts to promote phase maintenance in oscillator-follower networks. Depression allows synaptic and intrinsic mechanisms to interact to expand the range of frequencies over which phase is maintained. We show how depression allows the phase to be controlled by different biophysical parameters at different frequencies.

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**MS33**

## Divisive Gain Modulation through Noisy Background Synaptic Input

Responses of cortical neurons to sensory stimuli are extremely variable due to the constant barrage of fluctuating background input that these neurons receive. Using a combination of analytic calculations and experimental results, I will show that background synaptic input is not merely a source of noise. Rather, the level of background input act as a volume control that determines the gain of neuronal responses. This suggest that the high-input environment of the cortex allows neurons to perform multiplicative computations, and thus to act somewhat like transistors.

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**MS33**

## The Effects of Plasticity in Networks of Neural Oscillators

Spike-time dependent plasticity has been shown in a variety of neural systems. That is, the relative times between spikes between two connected neurons can determine whether the connections are strengthened or weakened. We describe a number of possible rules and show their consequences in the context of networks of neural oscillations. We exploit the slow changes due to plasticity to invoke the averaging theorem allowing us to analyze these networks.

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**MS34**

## Vortex Dynamics on the Tropopause

At a height of roughly 10 km, the tropopause defines the boundary between the upper troposphere and the lower stratosphere. Characterized by an abrupt jump in density stratification, the tropopause is an atmospheric interface upon which vertically-trapped vortices can be sustained. There is a recognized asymmetry, from both observations and computational models, that cyclonic (low pressure) vortices tend to be more intense and localized, while anticyclonic (high pressure) vortices tend to be weaker and broader. This situation holds not only for disturbances at smaller scales near the tropopause, but also cascades to larger scales which directly affect the North American weather pattern. Despite the pervasiveness of this asymmetry in the midlatitudes, the underlying fluid mechanics behind this bias remains poorly understood. The atmosphere is really a problem of rotating, stratified fluid mechanics. In the limit of small Rossby number, a 2D vorticity dynamics on the tropopause has been developed, which is being applied to understand the physical origins of the symmetry-breaking of atmospheric vortices. This work is in collaboration with C Snyder (NCAR), R Rotunno (NCAR) and G Hakim (Univ of Washington).

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**MS34**

## Generation of Large-scale Jets, Vortices and Layers from Near Resonant Interactions of Fast and Slow Waves

The dynamics of the earth's atmosphere are modeled by a hierarchy of PDEs, from the 2D beta-plane model to the 3D Boussinesq equations for stably stratified and rotating flow. We and others have demonstrated that small-scale turbulence leads to the generation of slow, large-scale, coherent structures such as jets, vortices and layers, depending on the strength of the stratification and rotation parameters. The role of resonant interactions in the generation of the slow modes is not yet fully understood, and thus we propose lower dimensional models to isolate and study the near-resonant interactions of fast waves and slow modes.

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**MS34**

## Dynamics in a World Driven by Turbulent Diffusion

Mixing of fluids with different properties (i.e. salinity, temperature, biological activity) is a critical process in establishing the response of the atmosphere and ocean to changes in external parameters. On the other hand, modeling mixing at a quantitative, and even a qualitative level, is hard, due in part to the broad spectrum of scales involved, and to the seemingly chaotic nature of its detailed dynamics. Present general circulation models often parameterize mixing by invoking a turbulent diffusive closure, in which the small scales are thought of as driven by nonlinear diffusion, with the diffusivity varying depending on the level of turbulent energy available. This talk will describe recent work in understandind the detailed dynamics of a fluid world driven by turbulent diffusion, and comparing it with alternative closures, and ultimately with physical experiments and real–world observations. Processes included are the formation of well–mixed layers, shear instability, and mixing by internal breaking waves.

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**MS34**

## The Coherence of Turbulence

Turbulence has been and, to a large extent, continues to be seen as the 'random collision of eddies' leading primarily to enhanced 'eddy'-diffusion roughly analogous to molecular diffusion. However, observations in various types of turbulence, be it shear-driven or convectively-driven, have revealed the existence and importance of coherent structures at almost any scale, from the large scale coherent structures seen in the atmosphere, to the near-wall coherent structures in wall-bounded shear flows. The presence and importance of these coherent structures are responsible for the relative successes of EOF (Empirical Orthogonal Eigenfunction) approaches. But the latter remain statistically based, ¡i¿ a posteriori,¡/i¿ approaches to coherent structure identification and modeling. I will focus on the example of wall-bounded shear flows where we are now able to directly calculate a class of unstable ¡i¿ Exact Co-

herent Structures ¡/i¿ that are traveling wave solutions of the Navier-Stokes equations. The physical mechanisms responsible for these coherent structures is well-understood and it is most likely that these small scale structures are closely connected with larger scale structures seen in geophysical flows, such as Langmuir vortices. I will demonstrate that these traveling wave solutions capture essential structural and statistical features of turbulent flows. The turbulent dynamics associated with the unstable exact coherent structures will be discussed on the basis of simple models as well as numerical simulations.

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## MS35

### Probabilities of Extinction, Weak Extinction, Permanence and Mutual Exclusion in a Discrete Lotka-Volterra Model with an Invading Species

The probabilities of various biological asymptotic dynamics are computed for a stable system that is invaded by another competing species. The asymptotic behaviors studied include extinction, weak extinction, permanence, and mutual exclusion. The model used is a discrete Lotka-Volterra system that models species that compete for the same resources. Among the results found are that the chance of permanence occurring in the invaded system is significantly higher than the probability of permanence in a purely random system, and that multiple extinctions that include the invading species and one of the original species are impossible.

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## MS35

### Chaotic Transients in Maps from Biological Population Models

Chaotic transient behavior is a common occurrence in difference equation models of biological populations. I will discuss the generic bifurcations which give rise to chaotic transients, specifically in relation to discrete population modelling. The results are extended naturally to ODE population models, through the use of Poincaré maps. The possibility of detection of chaotic transients in real biological populations through scaling of average transient lengths will be considered.

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## MS35

### Periodic Dynamical Systems in Genetics and Population Models

Several discrete time periodic genetic and population dynamic models are discussed. Each of these models are examples of the dynamical system

$$\left.\begin{aligned} x(t+1) &= F(t, x(t)), & x(0) = x \in R_+ \\ y(t+1) &= G(t, x(t), y(t)), & y(0) = y \in R_+ \end{aligned}\right\}$$

where $F : Z_+ \times R_+ \to R_+$ and $G : Z_+ \times R_+^2 \to R_+$ are continuous functions, and where there exists a smallest positive integer $T$ satisfying $F(t+T, x(t)) = F(t, x(t))$ and $G(t+T, x(t), y(t)) = G(t, x(t), y(t))$. The existence and stability of periodic orbits with special periods are discussed.
If $x_0$ is the start of a periodic orbit for $F(t, x(t))$, then the possible periods for a periodic orbit starting at $(x_0, y_0)$ are found. Necessary and sufficient conditions for the stability of this new periodic orbit are also developed.

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## MS35

### Generalized Henon Difference Equations with Delay

Charles Conley once said his goal was to reveal the discrete in the continuous. The idea here of using discrete cohomology to elicit the behavior of continuous dynamical systems was central to his program. We combine this idea with our idea of "expanders" to investigate a Henon-like difference equation of arbitrarily high finite dimension with a delay factor.

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## MS35

### Attractors for Discrete, Periodic Dynamical Systems and Applications to Models in Population Biology

This work presents a simple framework for studying attractors of discrete, nonautonomous dynamical systems which depend periodically on time. It is shown that an attractor for a system of period $p$ is the union of $p$ subsets which may be homeomorphic to one another. If the periodic system is a perturbation of an autonomous system then conditions are presented which guarantee that each subset is homeomorphic to an attractor for the autonomous system. Examples from population biology are discussed.

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**MS36**

### Force Generation by the Growth of Branched Actin Networks

The growth of branched actin networks often helps drive the motion of locomoting cells. We study the growth velocity V of such networks, using stochastic simulations which track all actin monomer coordinates, and rate equations based on the filament tip density. Our key findings are: 1) in autocatalytic models, V is independent of opposing force, and 2) V drops linearly with the concentration of actin capping proteins. Experimental tests of these predictions are discussed.

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**MS36**

### Cytoskeletal Mechanics and Spindle Morphogenesis During mitosis in Drosophila Embryos

Abstract not available at time of publication.

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**MS36**

### Large-scale Conformational Changes in Motor Proteins

Abstract not available at time of publication.

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**MS36**

### Energy Flow and Efficiencies of Molecular Motors

Abstract not available at time of publication.

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**MS37**

### Spiral Spectra

This talk focuses on the linear-stability spectra for spiral and scroll waves in excitable media. While leading eigenvalues for these waves were computed many ago, computations deep into the spectrum are extremely challenging. Yet, only though such computations can predictions made recently by Sandstede, Scheel, and others, be verified. I will describe the numerical approach to these computations and present results for the equal diffusion case considered by Sandstede and Scheel and also for the single diffusion case.

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**MS37**

### Traveling Hole Solutions of the Complex Ginzburg-Landau Equation

Traveling hole solutions of the complex Ginzburg-Landau (CGL) equation are coherent structures which asymptotically connect plane waves with different amplitudes and different wavenumbers. In the same way as spiral defects of two-dimensional CGL mediate a form of weak turbulence displayed by this equation, traveling holes seem to play an important role in the disordered dynamics of one-dimensional CGL at a finite distance past the Benjamin-Feir instability threshold. In this talk, I will present some stability properties of traveling hole solutions and discuss these structures in the broader context of weak turbulence in one-dimensional CGL.

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**MS37**

### Defects in Oscillatory Media - Towards a Classification

We propose a classification for localized structures in oscillatory media. In the class of general reaction-diffusion systems, we describe four typical phenotypes of defects embedded in a background of spatio-temporally periodic wave trains. All four types have been observed experimentally and can be realized as perturbations of the phase-slip vortex in the one-dimensional Ginzburg-Landau equation. The main characteristic is the sign of the group velocities on both sides of the defect, measured relative to the speed of the defect. We show that all four types occur in open classes of reaction-diffusion systems and characterize their spectral properties, crucial for stability, perturbation, and interaction properties of defects. The classification is based on a spatial-dynamics description, where typical defects correspond to robust homoclinic and heteroclinic connections in an ill-posed pseudo-elliptic equation.

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**MS37**

### Wave Propagation and Defect Dynamics in Excitable Systems with Anomalous Dispersion

We report experimental results on the dynamics of excitation waves in a modified Belousov-Zhabotinsky reaction. The waves in this system obey non-monotonic dispersion relations. This anomaly induces the stacking of excitation fronts into patterns with stable interpulse distances. The stacking process creates either a traveling shock structure or a cascade of bunching events in which metastable wave packets are formed. The direction and the speed of the shock are explained in terms of a simple geometrical analysis. We also present the first experimental evidence for the corresponding instabilities in two-dimensional systems. Here, wave stacking generates atypical structures in the collision of target patterns and wave bunching is ac-

companied by complex front deformations.

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### MS37

### Polymer Flow Instabilities: From Amplitude Equations to Turbulence?

When a polymer fluid is pressed through a tube, the "extrudate" shows irregular behavior above a certain flow threshold. The origin has been a long-standing puzzle. We attribute this behavior to a weakly subcritical instability of visco-elastic tube flow: our amplitude expansion to cubic order shows the flow is linearly stable but nonlinearly unstable. Recent experiments confirm quantitatively our scenario, which identifies the route to "turbulence without inertia", and which suggests new classes of amplitude equations.

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### MS38

### Reversible Methods for Collisional Dynamics with Applications in Statistical Mechanics

Hard-sphere systems were the first to be studied by molecular dynamics simulation. If the interactions are purely collisional, the dynamics of such systems can be resolved exactly using an event based algorithm which steps along linear paths between contacts. These classical algorithms must be modified if the dynamics is constrained to a manifold and long-range forces are introduced. We investigate geometric integrators for collisional dynamics of hard-spheres and rigid bodies on manifolds interacting in the presence of long-range potentials. In numerical experiments, the efficiency of each method is measured using its accuracy in resolving statistical mechanical averages.

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### MS38

### Discrete Exterior Calculus - Part II

We present a discrete exterior calculus for simplicial meshes and their circumcentric duals. Discrete notions of differential forms and vector fields are introduced, and the exterior derivative, wedge product, hodge star, codifferential, sharp, flat, contraction, and Lie derivative are constructed as combinatorial operations on the mesh. In addition, a discrete Poincaré lemma holds. In this framework, one can systematically recover discrete vector differential operators like the divergence, gradient, curl and the Laplace-Beltrami operator.

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### MS38

### Discrete Exterior Calculus - Part I

We present a discrete exterior calculus for simplicial meshes and their circumcentric duals. Discrete notions of differential forms and vector fields are introduced, and the exterior derivative, wedge product, hodge star, codifferential, sharp, flat, contraction, and Lie derivative are constructed as combinatorial operations on the mesh. In addition, a discrete Poincaré lemma holds. In this framework, one can systematically recover discrete vector differential operators like the divergence, gradient, curl and the Laplace-Beltrami operator.

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### MS38

### Introduction to Discrete Geometry and Geometric Integration

This lecture will serve as an introduction to the general topic of discrete mechanics, the associated variational integrators and discrete geometry, including discrete exterior calculus and AVI's (asynchronous variational integrators) for PDE's. The main focus will be on setting the stage for some of the lectures that follow.

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### MS38

### Approximate Momentum Conservation for Spatial Semidiscretizations of Nonlinear Wave Equations

We prove that a standard second order finite difference uniform space discretization of the nonlinear wave equation with periodic boundary conditions, analytic nonlinearity, and analytic initial data conserves moentum up to an error which is exponentially small in the stepsize. Our estimates are valid for as long as the trajectories of the full nonlinear wave equation remain real analytic. The method of proof

is that of backward error analysis, whereby we construct a modified equation which is itself Lagrangian and translation invariant, and therefore also conserves momentum. This modified equation interpolates the semidiscrete system for all time, and we prove that it remains exponentially close to the trigonometric interpolation of the semidiscrete system. These properties directly imply approximate momentum conservation for the semidiscrete system. We also consider discretizations that are not variational as well as discretizations on non-uniform grids. Through numerical example as well as arguments from geometric mechanics and perturbation theory we show that such methods generically do not approximately preserve momentum.

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**MS38**

**Approximation of the Matrix Exponential by Lie-group Techniques**

In this talk we explore the computation of the matrix exponential in a manner that is consistent with Lie-group structure. Our point of departure is the method of *generalized polar decomposition* associated to involutive automorphisms of the group. The method of generalized polar decompositions is combined with the use of similarity transforms that bring the undelying matrix in a form more amenable to efficient computation. We explore techniques for a range of Lie groups, like the orthogonal group, the symplectic group, special linear group. Even when Lie-group structure is not at issue, our algorithm is more efficient in many settings than classical methods for the computation of the matrix exponential.

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**MS39**

**Point Vortex Models for Wakes and Shear Layers**

Point vortex models of wakes and shear layers have been a mainstay of the theory of such flows since the early analytical and computational studies by von Karman, Rosenhead, and others. In recent years there have been some interesting developments related to what one might call complex wakes, e.g., vortex streets with more than two vortices shed per period. The presentation will survey such results drawing on experiments, numerical simulations and analysis of the point vortex equations.

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**MS39**

**Topological Analysis of Point Vortex Dynamics**

The motions of singly-periodic arrays of point vortices are studied. Symmetries reduce each system to a one-degree-of-freedom Hamiltonian whose phase portrait is subdivided into regimes. A braid describes the topology of all motions in each regime as well as the isotopy class of the induced advection homeomorphism. The Thurston-Nielsen theory allows an analysis of the isotopy classes revealing a mechanism by which the topological kinematics of large-scale, two-dimensional fluid motions generate chaotic advection.

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**MS39**

**Vortex Models of Inertial Range Turbulence**

The evolution of initially weak structures of vorticity as they evolve in an incompressible turbulent flow is investigated. Such objects are candidates for important structures in the inertial range and in the dissipation range of scales. Initially, these structures evolve passively by the induced velocity field of the large-scale vorticity field. This field is three-dimensional and time-dependent so that these objects are subjected to straining apropos of lagrangian chaos, characterized by a distribution of finite-time Lyapunov exponents.

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**MS39**

**Monte-Carlo and Polyhedra Based Algorithms for Extremal Energy States in the Vortex N-body Problem**

The problem of N bodies on the surface of the sphere interacting by a logarithmic potential is examined for selected N ranging from 4 to 40,962, comparing the energies found by placing points at the vertices of certain polyhedrons to the lowest energies found by a Monte Carlo algorithm. The polyhedron families are generated from simple polyhedrons through two triangular face splitting operations which are used iteratively to increase the number of vertices. The closest energy of these polyhedron vertex configurations to the Monte Carlo-generated minimum energy is identified and the two energies are found to agree well. Finally the energy per particle pair is found to asymptotically approach a mean field theory limit of $-\frac{1}{2}(log(2)-1)$, approximately 0.153426, for both the polyhedron and the Monte Carlo-generated energies. The deterministic algorithm of generating polyhedrons is shown to be a method able to generate consistently good approximations to the statistical extremal energy configuration for a wide range of numbers of points.

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**MS39**

**Vortex Buckyballs and Other Particle Clustering**

**Patterns Far from Equilibrium**

When point vortices are arranged to lie at the 60 vertices of a truncated icosahedron, dynamical clustering ensues with 12 groups of 5 vortices moving in periodic orbits on the surface of a sphere. Since the original structure is identical to a Buckyball, we call such objects 'Vortex Buckyballs'. This is just one of many interesting non-equilibrium objects that are formed from the Platonic and Archimedean solids when vortices are placed at each vertex, and this talk will describe the bifurcations from one orbit class to another, as well as the Floquet spectrum and the Huckel theory of molecular stability associated with these objects.

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### MS39
**Vortex Lattice Dynamics**

A doubly-periodic lattice of identical discrete vortices is one system that dynamically influences an infinite fluid region while having only a few degrees of freedom. The dynamics become significantly more complex and interesting when considering a number of inter-penetrating lattices with differing strengths, yet the problem remains mathematically tractable. A general formulation of the equations governing such lattice systems will be presented, and the dynamics and statics of several cases will be discussed.

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### MS40
**Bifurcation Bridges in Lasers Subject to Optical Feedback**

Semiconductor lasers subject to delayed optical feedback exhibit isolated branches of steady state intensities. We show numerically and analytically that bifurcation bridges are connecting these branches and that they play a key role in the bifurcation diagram. Physically, these bridges correspond to rapidly pulsating intensity regimes, which are useful for applications. Mathematically, we solve the delay differential equations describing the laser by a singular perturbation analysis that takes advantage of the laser's natural parameters.

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### MS40
**Delay Dynamics of Diode Lasers with Short External Cavities**

We present a detailed analysis of the dynamics of semiconductor lasers subject to external feedback from a short cavity. When experimentally varying the external cavity round trip phaseand measuring fast real-time intensity time series and optical and rf spectra, we find a scenario leading from stable to periodic emission via regular and irregular pulse packages back to stable emission. We use extensive numerical modeling and bifurcation analysis to explore the underlying mechanisms.

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### MS40
**A Two-parameter Study Near the Locking Range of a Semiconductor Laser with Phase-conjugate Feedback**

We present a detailed two-parameter bifurcation analysis of a system of delay differential equations describing a semiconductor laser subject to phase-conjugate feedback. With new numerical continuation techniques we find curves of local bifurcations and curves of heteroclinic orbits. Furthermore, we identify several codimension-two bifurcations, namely a double-Hopf point, a Belyakov point and a T-point, and show how they organize the dynamics of the laser.

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### MS40
**Stability Analysis of External Cavity Modes in the Lang-Kobayashi Equations**

A semiconductor laser with delayed optical feedback can be described by a three-dimensional delay differential system called the Lang-Kobayashi (LK) equations. We use general theory for delay differential equations to analyse the stability properties of external cavity modes, periodic orbits that are invariant under the $S^1$-symmetry of the LK-equations. This is a necessary step towards a mathematical explanation of how the so-called low frequency fluctuations develop in lasers with optical feedback.

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### MS40
**Computation of Connecting Orbits in Delay Differential Equations**

We discuss the capabilities of the Matlab package DDE-BIFTOOL for the numerical bifurcation analysis of delay

differential equations, emphasizing the computation of connecting orbits between steady states. Such a connecting orbit is approximated by solving a boundary value problem with so-called projection boundary conditions onto the respective linear stable and unstable eigenspaces. Since the stable eigenspace is infinite-dimensional, the associated end condition needs to be formulated by using a special bilinear form.

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**MS40**

**Dynamics of Multi-Section Lasers**

Multi-section lasers can be designed so that a variety of nonlinear effects, known to exist in lasers with delayed optical feedback, can be used in telecommunication engineering. Due to the shortness of the integrated cavity the underlying dynamics is low-dimensional.This property can be exploited to reduce infinite-dimensional models (DDEs or PDEs) to low-dimensional ODEs that can be studied with classical tools from bifurcation theory.

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**MS41**

**A Weakly Nonlinear Approach to Complex Tidal Dynamics**

In this talk we study the dynamics of a tidal basin that is connected to a sea. The tide within the basin is driven by the tide at sea. The system is modeled by a shallow water equation with boundary conditions prescribed by the external tide. This model can be studied by the methods of weakly nonlinear stability theory, which results in a system of coupled Landau equations. We shall discuss various mechanisms in this Landau system by which complex/chaotic tidal dynamics may be generated.

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**MS41**

**Analysis and Prediction of Nonlinear, Nonstationary Coastal Water Levels**

Previous studies have shown that coastal water levels can be characterized as low dimensional chaotic-like systems with additive noise. Further, depending on the time scales, water levels can be treated as a nonstationary system. Thus, the data presents itself as a broad-band signal in nongaussian, nonstationary noise The difficulty in characterizing and predicting such systems is that the body of research presumes the underlying system is embedded in Gaussian noise and is wide sense stationary. This paper will discuss the challenges to characterization and prediction of broad-band data in nonideal environments.

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**MS41**

**Non-Stationary Tidal Processes in Estuaries**

Estuarine tides are non-stationary on multiple time scales and for a variety of reasons. Broadly speaking, non-stationary behavior may arise either during generation (especially for internal tides) or during propagation, through modulation by non-tidal processes. This talk explores phenomena, causes and analysis methods for tidal processes that are non-stationary on four time scales: event, tidal monthly, seasonal and longer term. Fluctuating river flow (e.g., from floods, variable glacial outflow and reservoir manipulation) and storms may modulate surface tides and tidal salinity variability on time scales from hours to days. Estuarine tidal currents, fjord internal tides, and tidal variations in suspended sediment concentration are strongly influenced by changes in the density field, inducing approximately tidal monthly variations. Seasonal cycles of river flow, ice cover and atmospheric forcing may also influence surface tides. Interannual to century-scale variability in tides occurs both due to human modification of estuaries and perhaps because of climate-induced changes in the coastal ocean; mechanisms are poorly understood. Methodological challenges abound, but are most severe when the relevant non-tidal processes have time-scales of a few days or less.

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**MS41**

**Dynamics of the Storm Gates for Protecting Venice Lagoon**

To protect the island city of Venice from frequent flooding, storm barriers have been proposed to span the three inlets of Venice Lagoon. The design under consideration consists of a series of hollow steel gates unconnected to their neighbors but are hinged at the bottom along a common axis on the seabed, in order to limit the cost of the supporting structure. In calm weather the gates rest horizontally on the seabed so as not to obstruct normal navigation or natural flusing of the lagoon by tides. When a storm is expected, all gates will be raised by buoyancy to an inclination of about 50 degrees from the horizontal. They are expected to swing to and fro in unison in normally incident waves while keeping the storm tide outside the lagoon. Laboratory experiments with simple harmonic incident waves performed in Delft and Italy have however shown that neighboring gates may oscillate out of phase in a variety of ways, at half of the frequency and with relatively large amplitude. This unexpected phenonmenon of subharmonic resonance suggests that there exist situations where the efficiency of the gates as a dam may be much reduced. It will be shown first that the root of the subharmonic resonance is the existence of trapped modes similar to bound states in quantum mechanics. A related phenomenon in sea waves is the edge wave on a sloping beach,

which can only be excited nonlinearly (Guza & Bowen, Rockliff, Minzoni & Whitham) . We first describe a linearized theory for the eigen modes and the dispersion relation between frequency and wavelength, for both vertical and inclined gates. Results for the former case imply that trapping is caused by the articulated design and not by the inclination. Unlike the usual cases in accoustic resonators, the most undesirable mode has the highest frequency and shortest wavelength, involving pairs of neighboring gates ocscillating in opposite phase. Expermental confirmation of the eigen values will be shown. Next, laboratory evidence in a long tank for subharmonic resonance of this mode will be discussed. A weakly nonlinear theory will be presented for the slow evolution of the complex amplitude of the gate oscillation. As expected, the Landau-Stuart equation governs the angular motion of the gate system. While in principle the basic theory is similar to that of the edge wave problem, the task of deducing the coupling coefficients is however not trivial since a number of radiation and scattering problems must be solved in the perturbation analysis. Detailed knowledge of the coefficients in the evolution equation is essential for the prediction of gate performance such as the growth rate and equilibrium amplitude at resonanceas functions of the geometry of the gates, channel, and wave characteristics. For uniform incident waves, bifurcations involving hysteresis will be confirmed experimentally. In additon, we shall report theoretical consequence of periodc modulation of the incident waves, (the simplest model of narrow-banded sea). The Landau-Stuart equation now has a periodic coefficient, yielding a non-autonomous dynamical system. Experimental confirmation of the predicted bifurcations involving period-doubling and strange attractors will be shown. The prototype geometry resembles that of a long tank only on the Adriatic side, by the presence of long inlet jetties. On the lagoon side there is open space. Recent work on the 3-D diffraction-radiation problem will be discussed. New tasks on nonlinear theory will be outlined.

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## MS41

### Nonlinear Response of a Cooscillating Tidal Basin; Theory and Laboratory Experiments

Tides in coastal areas can reach considerable amplitude due to resonance in basins cooscillating with a connected sea. Nonlinear effects on the resonance characteristics will be discussed. Nonlinearities in the system arise due to e.g. friction, advective accelerations and the geometry of the basin. Friction can be dealt with using so-called Lorentz linearization, more complex dynamics may result from advective accelerations and nonlinear geometry effects. Apart from discussing theoretical models, laboratory experiments will be presented.

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## MS41

### Tide-topography Interaction and Morphologic Pattern Formation

Time plots of observed sea surface elevations and currents in shallow tidal seas with a sandy bed are often highly asymmetrical. Moreover, the degree of asymmetry varies strongly on a spatial scale that is small compared to the tidal wavelength. These observations indicate the presence of tidal components that are locally generated by nonlinear processes. One important mechanism that causes the generation of nonlinear tides is the interaction of the large-scale tidal wave with the irregular topography of the domain. In turn, tidal currents also reshape the bottom by eroding and transporting the sediment. The resulting evolution of morphologic patterns takes place on a timescale that is generally much larger than the tidal period. In this presentation results will be presented of models that describe the generation of nonlinear tides and related morphologic patterns. The models explicitly describe the feedback between tidal motion, transport of sediment and evolution of the bottom. To obtain solutions the tidal averaging method is applied: the hydrodynamics is computed for a fixed bed level and the bottom evolution is determined by the divergence of the tidally averaged sediment flux. First, it will be demonstrated that numerical models can simulate the formation of observed morphologic patterns (outer delta of a tidal basin, bathymetry of the North Sea) quite well. However, owing to their complexity, such models are not suitable to unravel the underlying dynamics. Alternatively, more idealized models have been developed which allow for an explorationy with mathematical methods (stability and bifurcation analysis). It will be shown that nonlinear tides and rhythmic bed forms can initially form due to an inherent instability of the coupled water-bottom system. The specific example will concern the formation of channels and sandy shoals in a long tidal embayment (length of the order of the tidal wave-length). The finite-amplitude behaviour of the tidal components and bedforms is modelled by spectral methods, using the eigenmodes of the linearized system as expansion modes. This results in a dynamical system consisting of differential equations (for the amplitudes of the bottom modes) and algebraic equations (for the tidal modes). A bifurcation analysis reveals the possible co-existence of different stable morphodynamic equilibria. Moreover, depending on the model parameters, periodic solutions (and indications of more complex) solutions are found.

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## MS42

### The Visual Cortex as a Crystal

A theory of pattern formation in primary visual cortex (V1) is presented that takes into account its crystalline-like structure. The cortex is partitioned into fundamental domains or *hypercolumns* of a lattice describing the distribution of singularities or *pinwheels* in an underlying orientation preference map. Interactions between hypercolumns are mediated by anisotropic long range lateral connections that link cells with similar orientation preferences. Using weakly nonlinear analysis we investigate the spontaneous formation of cortical activity patterns through the simultaneous breaking of an internal $O(3)$ symmetry and a discrete lattice symmetry.

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### MS42
### Nonlinear Coupling Near a Subcritical Hopf Bifurcation

Recurrent connections can lead to coupling-induced bistability. Recent investigations of coupled neurons near a Hopf bifurcation lead to a theory of linear coupling but this cannot lead to bistability. Rather, we employ nonlinear coupling near a Hopf bifurcation to obtain a system of the form

$$z_t = z * f(|z|, q) + K(x) * (|z(x)|^2 z(x))$$

where $K(x)$ is a spatial convolution and $q$ parameterizes the function $f$ so that when $q = 0$ $f$ is real. We show that for $q$ sufficiently small, there are traveling wave fronts joining $z = 0$ to $z = R\exp(ik(x - ct))$. For large enough $q$, there are localized regions of excitation.

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### MS42
### Spatial Patterns Rising in Cancer Models

Cancer evolution can be formulated as a free boundary problem where the tumor/stroma interface is a priori unknown. Since the problem is mathematically quite hard, most of the mathematical models consider only the radially symmetric case so that the cancer region is spherically symmetric. In this talk, I shall report on results concerning the existence of non-spherical tumors. These results can be described as symmetry-breaking bifurcations. I shall also state some asymptotic stability results for the non-radially symmetric case.

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### MS42
### Cortical Architecture and Patterns of Response in the Primary Visual Cortex

In this lecture, we will describe relationships between cortical wiring architecture, functional maps and the response properties of neurons within the layers of the primary visual cortex. The cortical map of orientation selectivity will be emphasized. Both the experimental and computational results contrasting responses for neurons near and far from orientation pinwheel centers will be described. Large scale numerical simulations and their coarse grained reductions will be used to gain theoretical insight into the mechanisms which create these response properties.

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### MS42
### Multi-Bumps in Two Dimensional Nonlocal Problems

We investigate multi-bump formation in time dependent integro differential equations in two space dimensions. For appropriate coupling functions a partial differential equation is developed which approximates the integral equation. A linearization around an axially symmetric solution predicts (i) if a peruturbation will evolve into a multi-bump solution, and (ii) how many peaks will form in the resultant PDE solution.

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### MS43
### Regularization Modeling of Rotating Turbulence

The effects of rotation on turbulence in single and double shear layers will be considered. The quality of regularization models, including Leray's approach and formulations based on the Euler-Poincare equation will be assessed and compared with more traditional large-eddy simulation. This is joint work with Darryl Holm.

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### MS43
### The Scaling Structure of Velocity Statistics at High Reynolds Numbers

I will first briefly review the well-known predictions for statistically homogeneous and isotropic high Reynolds number turbulence, which date back to 1941 (Kolmogorov). I will then present more recent work on flows with broken rotation symmetry (anisotropy) and describe the SO(3) group decomposition methods used to extract anisotropic behavior. Finally, I will show new results which predict the scaling behavior due to the breaking of reflection-symmetry in the velocity field; this result is the counterpart to the Karman-Howarth equation of 1938 for reflection-symmetric flows. Each of these steps contributes to completing the picture of the scaling structure of statistical hydrodynamics. Experimental and numerical results from various sources will be presented where appropriate.

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### MS43
### New Approaches in Modeling GFD Turbulence

Mesoscale turbulence in the atmosphere and ocean profoundly influence transport of mass, momentum, and other important passive scalars. However, since we cannot afford to resolve these scales on the long timescales of interest to climate studies, it is of importance to be able parameterize their effects on the larger scales. We investigate the utility of alpha-models and other related models as bases for Large Eddy Simulation approaches to parameterizing

mesoscale turbulence in some typical GFD flows.

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MS43

### Is There Universality in the Presence of Waves: The Case of Magnetohydrodynamic Turbulence

In 1941, Kolmogorov derived three scaling laws concerning turbulent flows (K41), namely for their energy spectrum for the decay of energy and finally an exact law giving the scaling of third-order structure functions. Homogeneity, isotropy, incompressibility, stationarity are assumed and the limit of large Reynolds numbers is taken in these approaches. Iroshnikov and Kraichnan both proposed a modification to the phenomenology for magnetohydrodynamic (MHD) turbulence; they took into account the fact that in the presence of a large-scale magnetic field, only oppositely-propagating Alfvén waves along the field interact nonlinearly. The ensuing total (kinetic+magnetic) energy spectrum, and decay law can be derived. The MHD relationship corresponding to the exact "4/5th" law of Kolmogorov involves cross correlations between the velocity and the magnetic field. The consequences of such laws for the anomalous scaling of higher-order structure functions, and the role they play in the study of spatio-temporal intermittent structures will also be mentioned. In particular, an analysis is reported which characterizes the scaling behavior of the sign-oscillating flow structures, and their geometrical properties linked to the fractal dimension of the structures in the flow. Topological changes of the photospheric magnetic field inside active regions can similarly be viewed as a prelude to large flares.

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MS43

### On the Leray Model of Turbulence

We consider the Leray smooth approximation to the Navier-Stokes equations (NSE) as a system of PDEs by its own right. Estimates to the dimension of its global attractor are comparable to the number of degrees of freedom suggested by classical turbulence theory. Up to a certain wave number in the inertial range of the Leray model (LM) the energy power spectrum obeys the Kolmogorov power law. However, for the rest the inertial range the it obeys a faster decaying power law. This observation makes the LM more computable than the NSE, and a suitable sub-grid turbulence model. By implementing the LM as a closure model to the Reynolds averaged equations of the NSE one gets a very good agreement with empirical and numerical data of turbulent flows in infinite pipes and channels.

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MS44

### Discrete and Continous Models of Fish Populations

Discrete and continous models of fish populations in the North Atlantic will be discussed. The numerical analysis of such problems can be difficulty due to ill-posedness of the initial value problems. In some cases a low-dimensional theory of basic attractors can be used. In other cases stochastic partial differential equations play a large role.

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MS44

### Neighbor to Neighbor: Relating Individual to Group Behaviors in Schooling Fish

We quantified relative movements of schooling fish in large aquaria, and developed neighbor-response algorithms approximating observed behaviors. We then used simulations and mathematical analyses to predict characteristics of social groups (group size, speed, cohesion, directional persistence, etc.) and the resulting population fluxes at large spatial and temporal scales. Coupled individual-population models allow us to explore the evolutionary and ecological context of social behaviors in ways that are inaccessible from either perspective in isolation.

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MS44

### Geometry of Steering Laws in Cooperative Control

The idea of studying the Frenet-Serret equations as a control system perhaps goes back to the seventies if not earlier. In this talk we will consider such moving frames associated to a bundle of curves interpreted as trajectories of a set of unmanned aerial vehicles moving at unit speed. We discuss the geometry of interactions between the frames via coupling laws between the frame invariants (curvature and torsion). We show that there exist interesting choices of such coupling laws that cause coherent bundling of curves (equivalently formation stabilization). This is joint work with Eric Justh.

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MS44

### Abstractions and Control Policies for a Group of Vehicles

We address the problem of controlling a large number of agents required to move while maintaing constraints on the shape of the formation. If information about the state of each agent is available to all agents, this problem can be easily solved. However, such approaches are impractical for a large number of agents. We propose an abstraction of the group as a low-dimensional manifold and consider the

design of vector fields on this manifold. We then develop decentralized control policies for each agent that realize this abstraction. We show that this scheme only requires feedback of information about the group (and not about individual agents) and demonstrate applications to a network of ground and aerial vehicles.

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**MS44**

**Collective Motion Algorithms for Determining Environmental Boundaries**

We develop a mobile robot path planning method for a swarm of homogeneous agents in a stationary environment. The agents cooperatively locate the boundary of a given environmental function in two space dimensions. Starting from a partial differential equation (PDE) that arises from a gradient flow energy minimization, a finite difference approximation provides the movement rules for each agent. The communication between agents may be either local or global and the stability of the algorithm using different communication rules is discussed. We also show through numerical simulations that the cooperative algorithm is robust to failure of some of the agents.

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**MS44**

**Dynamics of a Two-dimensional Continuum Model for Swarming**

Biological swarms often occupy a well-defined spatial region within which the population density is roughly constant. One difficulty in modeling swarms has been to construct continuum models which reproduce this phenomenon. We study a simple model for swarms in two dimensions. The population density satisfies an advection equation. The velocity depends nonlocally on the density by means of a convolution with a spatially decaying kernel, which describes the social interaction between organisms. Using the Hodge decomposition theorem, the velocity field may be decomposed into a divergence-free component and a gradient component. This framework provides a convenient way to characterize the two-dimensional dynamics. The gradient component controls the expansion or contraction of the population, while the divergence-free component is responsible for its rotational motion. Numerical simulations of the model reveal vortex states similar to those observed in nature.

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**MS45**

**Cooperative Effects of Noise in Homoclinic Chaotic Systems**

Homoclinic chaos consists in trains of erratically repeating geometrically regular spikes, and is conjectured to underly some aspects of neuronal dynamics. In these conditions, addition of very small amounts of noise leads to many constructive effects, such as noise induced synchronization, noise enhanced phase synchronization, coherence resonance and stochastic resonance. We give evidence and characterize such effects both theoretically and experimentally in a $CO_2$ laser system with intracavity electrooptical absorber.

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**MS45**

**Patterns of Synchrony in Coupled Cell Networks**

A coupled cell system is a network of dynamical systems, or 'cells', coupled together. A symmetry is a cell permutation that preserves internal dynamics and couplings. Symmetry can lead to synchronized cells, rotating waves, and multirhythms. We ask whether symmetry is the only mechanism that can create such states, and show that it is not. The key idea replaces the symmetry group by the symmetry groupoid. Necessary and sufficient conditions for robust synchrony will be given.

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**MS45**

**Dynamics of Delayed, Paired Excitatory-inhibitory Neural Feedback**

We examine the effects of delayed excitatory and inhibitory feedback on a single integrate–and–fire neuron with reversal potentials, with and without noise. We find that such a paired delayed feedback loop can act as a sophisticated computational unit, capable of quiescence, periodic firing, modulated firing/bursting, and various forms of bistability, depending on the input current, the relative strengths and the asymmetry of the properties of two feedback pathways,

and the loop delay distributions and noise level.

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### MS45

**Slow and Fast Inhibition Interact to Create a Theta Rhythm in CA1**

We describe a model of the mechanism of generation of oscillations in the theta frequency range (3-10 Hz) in the absence of phasic excitation. Our model consists of O-LM cells, standard interneurons and excitatory pyramidal cells. All the cells are modeled with standard currents of Hodgkin-Huxley type. In addition, O cells have persistent Na and h (hyperpolarization activated) currents. We provide an explanation of this mechanism in terms of the currents involved in the model.

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### MS45

**Cortical Information Encoded Jointly by Random and Pattern Spike Trains**

The method by which cortical information is encoded is presently a matter of discussion. I propose an approach where random and pattern firing are both needed for an optimal encoding. A novel pattern detection algorithm that works without templates and for which analytical results are obtained, will show that indeed both firing behaviors are present in ordinary in vivo data. Detailed neuron modeling will provide details of how the actual encoding proceeds by synchronization of phases.

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### MS45

**Development of Deep Brain Stimulation Techniques with Stochastic Phase Resetting Methods**

Based on novel, effectively desynchronizing stimulation methods deep brain stimulation (DBS) techniques have been designed which aim at a desynchronization of pathologically synchronized neural activity. In contrast, the standard deep brain stimulation is a permanent high-frequency (¿ 100 Hz) electrical pulse train stimulation which basically suppresses the firing in particular target areas. However, synchronized activity in particular target areas is the hallmark of Parkinson's disease, while under healthy conditions neurons in these areas fire in an uncorrelated way. The talk is about both theory and first experimental results.

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### MS46

**Wave Propagation in Periodically Modulated Cortical Media**

We consider the existence and stability of stationary and traveling pulses in a one-dimensional inhomogeneous neural medium. Motivated by the functional architecture of visual and prefrontal cortices, we model the inhomogeneity as a periodic modulation in the long-range synaptic connections. We derive expressions for the effective wave speed of a pulse using perturbation methods and determine conditions for wave propagation failure. We also show how periodic inhomogeneities can generate multistable solutions.

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### MS46

**Multiple-spike Waves in One-dimensional Integrate-and-fire Neural Networks**

Extending previous studies, numerical and analytical methods are combined to provide a framework for studying synaptically generated waves in one-dimensional networks of integrate-and-fire neurons. The focus of this presentation is to describe the spatio-temporal relationships between constant speed traveling waves located at large distances from their initiation region and to show under which conditions infinite-spike wave solutions converge to periodic wave ones. Findings from numerical experiments, where waves are generated by the transient application of localized excitation, are compared to results from theoretical methods for networks with finite and exponential connectivity functions.

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### MS46

**Analysis of Traveling Pulses in a Continuous Synaptic Network**

In this presentation, I will review a set of integral equations used to describe activity in a spatially extended and synaptically connected neural network domain. An analysis of traveling solutions to these equations draws from techniques used for the analysis of the same solutions to differential equations, but are complicated by the presence of nonlocal interactions. I will indicate some of these complications by presenting several strategies for examining the existence and stability of traveling pulse solutions on a one-dimensional spatial domain.

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### MS46

**The Simple and the Complex of Feature Selectivity**

**in V1**

The visual cortex detects elementary features of the visual scene while operating on many space- and time-scales and on both ordered and disordered feature maps. I will discuss the application of mean-field models of a V1 neuronal network to understanding the selectivity of the visual cortex, such as for orientation and spatial frequency of visual patterns, and for understanding how Simple and Complex cells can emerge from a single circuit. I will show that the recurrent interactions that differentiates between Simple and Complex cellular responses lead to different mechanisms of feature selectivity.

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**MS47**

**Chaos Associated to Weak Capture and Low Energy Transfers**

We prove a new result that unifies two types of seemingly unrelated types of capture in the circular restricted three-body problem. One is 'permanent capture' which is globally defined, and proven by Llibre, Simo in the 80's, and then by Xia in 92 to be associated to a hyperbolic invariant set, H. Another type of capture locally defined is called weak ballistic capture. This capture type has many applications, most notably it was demonstrated by the Japanese lunar spacecraft Hiten in 1991. The set describing weak ballistic capture is called the 'weak stability boundary', W. Weak ballistic capture is proven to be chaotic by proving that W has a nontrivial intersection with H.

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**MS47**

**On the History of the Slingshot Effect and Cometary Orbits**

The gravity-assist effect that now plays such an important role in the applications to modern space probes is essentially not any different from the planetary perturbations (mainly Jupter) of nearby comets. Because of these reasons, we briefly summarize some of the more important articles on the gravity effect on comets by Jupiter and on cometary perturbations in general. We specifically mention those that seem to have concrete information on the gravity-assist phenomenon.

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**MS47**

**Exploiting Unstable Periodic Orbits of a Chaotic Invariant Set for Spacecraft Control**

The purpose of this work is to show that the chaos control techniques can be used to efficiently keep a spacecraft around another body performing elaborate orbits. We consider a satellite and a spacecraft moving initially in coplanar and circular orbits, with slightly different radii, around a heavy central planet. The spacecraft, which is the inner body, has a slightly larger angular velocity than the satellite so that, after some time, they eventually go to a situation in which the distance between them becomes sufficiently small, so that they start to interact with one another. This situation is called as an encounter. In previous work we have shown that this scenario is a typical situation of a chaotic scattering for some well-defined range of parameters. Considering this scenario, we first show how it is possible to find the unstable periodic orbits that are located in the chaotic invariant set. From the set of unstable periodic orbits, we select the ones that can be combined to provide the desired elaborate orbit. Then, chaos control technique based on the OGY method is used to keep the spacecraft in the desired orbit. Finally, we analyze the results and make considerations regarding a realistic scenario of space exploration.

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**MS47**

**Uncertainty and Effective Dimension in Astrophysics**

We consider the escape of stars or other objects from within axisymmetric galactic potentials. For typical potentials, the boundary in phase space that separates different kinds of escapes is fractal. If the dynamics is non-hyperbolic, with KAM islands in phase space, the dimension $d$ of the boundary is maximal, and equal to the dimension of the full phase space $d_{ph}$. We show in thi talk that for a limited available resolution, the uncertainty in the escape is given by a quantity we call the *effective dimension* $d_{eff}$, which is different from the true dimension $d$, and satisfied $d_{eff} < d$. $d_{eff}$ depends on both the available resolution and the position in phase space. In other words, the effective uncertainty in the final fate of a given trajectory depends on where the initial conditions are taken. We apply these results to axisymmetric potentials, that are relevant for modelling galaxies.

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**MS48**

**The Dynamics of Nematic Polymers in Laminar Flows: A Zoo of Bifurcations Associated with Bulk Molecular Phase Transitions**

Nematic polymers are pervasive in biological as well as synthetic "soft matter" materials, and are responsible for remarkable material properties ranging from strength, elec-

trical and thermal conductivity, and impermeability. These macromolecules are distinguished by highly anisotropic shapes, so that collectively, above a critical concentration, a spontaneous ordering transition occurs (the isotropic-nematic phase transition). The Tobacco Mosaic Virus and spider silk are rod-like polymers, whereas nano-clays and carbon pitch are platelets. Bulk properties of nematic polymer and nano-composite materials are controlled by features, dynamical and morphological, which are created during flow processing. This lecture summarizes work of our research group on theory, modeling, and simulation of nematic polymers in laminar flows. Specifically, we will amplify the important role of bulk homogeneous molecular phases, called monodomains, which serve as precursors to structure formation. We show why multi-scale theory and simulations are essential, due to inherent limitations and sensitivity of traditional continuum and mesoscopic models, compelling a focus on kinetic theory. The latter part of the talk will highlight results of our group. Our research group includes Qi Wang, Florida State, Ruhai Zhou, UNC-CH, and Hong Zhou, UC-Santa Cruz, together with graduate students Eric Choate, Joohee Lee, Lingxing Yao, and Xiaoyu Zheng at UNC-CH.

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### MS48

### Comparisons Between Models of Dynamic Contact Lines

Abstract not available at time of publication.

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### MS48

### Drop Pinch-off and Filament Dynamics of Wormlike Micellar Fluids

Observations are presented of several novel phenomena involved in the dynamics of a pendant drop of viscoelastic micellar fluid falling through air. Generally, when a drop falls a filament forms connecting it to the orifice; the filament eventually breaks due to an instability. The filament dynamics and instabilities reported here are very different from the standard Newtonian and non-Newtonian cases. At low surfactant concentration, the cylindrical filament necks down and pinches off rapidly ($\sim$ 10 ms) at one location along the filament. After pinch-off the free filament ends retract and no satellite drops are produced. At higher concentrations, the pinch-off also occurs along the filament, but in a more gradual process ($\sim$ 1 s). Furthermore, the free filament ends do not fully retract, instead retaining some of their deformation. The falling drop is also observed to slow or even stop (stall) before pinch-off, indicating that sufficient elastic stress has built up to balance its weight. We investigate this stall by generalizing Keiller's simple model for filament motion, using instead the FENE-CR constitutive equation. Numerical simulations of this model indicate that stall occurs in the range of low solvent viscosity, high elasticity, and high molecular weight.

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### MS48

### Nonlinear Instability of Contact Lines in Thin Film Flows Driven by Marangoni Forces

We present an experimental and numerical study of the nonlinear instability of contact lines in thin film flows driven by thermally induced Marangoni forces. Small transverse perturbations to a uniform liquid front advancing up an inclined plane lead to the development of fingering patterns. By imposing perturbations with known wavelength to the initial conditions, we observe long-time convergence to finite amplitude fingers (two-dimensional traveling wave solutions).

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### MS49

### Feedback and Control in the Metabolism of E. Coli

A model of the PEP-depending sucrose phosphotransferase systems (PTS) describing by 19 ODES uptake and metabolism of sucrose is analyzed. Several reactions are quasi-stationary. The reduced model reveals PTS is not only used for transport and signal transduction, but also as a controller of the glycolytic flow. Approximately, the glycolytic system has an integral behavior feed back by a static gain in the PTS controlling the flow through the glycolysis.

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### MS49

### The Apoptotic Decision in TNF-treated Cells: Combining Experimental and Mechanistic Modeling Approaches

Apoptosis is controlled by integration of information from pro- and anti-apoptotic signaling pathways. In different cell lines, TNF-induced apoptotic responses differ in time scale, amplitude, and sensitivity to inhibitors. We have developed an ODE model of TNF-induced signaling, trained

with data from HT-29 cells. We combine quantitative measurements of signaling events with mathematical simulations to identify parameters predictive of a cell line's responses to apoptosis-inducing ligands and to assess robustness and fragility within the system.

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## MS49

### Feedback as a Remote Sensor in Cellular Signal Transduction

The JAK-STAT pathway is believed to be a feed-forward signalling cascade from receptors at the cell membrane to DNA in the nucleus. Based on this hypothesis we were not able to model time-resolved measurements of involved proteins. To explain the dynamics a nucleocytoplasmatic feedback has to be assumed. The analysis shows that STAT cycles through the nucleus in six minutes. By this cycling the system forms a "remote-sensor" to couple DNA-transcription closely to receptor activation.

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## MS49

### Bode's Integral Formula as a Conservation of Fragility Law for Feedback Systems

There are limits to the regulation of complex systems by feedback control. Bode's integral formula captures one aspect of these limits by describing a robustness tradeoff: reducing the sensitivity of a system at one range of frequencies by feedback control will amplify transients and oscillations at other frequencies. The main result of this work is the generalization of Bode's integral formula from linear to nonlinear feedback systems.

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## MS50

### Spatiotemporal Dynamics and Control of Thin Liquid Films: Experiments and Theory

Countless technological applications depend on precise control of fluid flow at small scales. Examples range from the widely-used industrial process of coating to the recently developed techniques of microfluidics for chemical and biochemical analysis/synthesis on "labs-on-a-chip". Control of flow at small scale can also advance fundamental understanding of pattern formation in many physical and biological systems, for example, permitting the investigation of otherwise unobservable, unstable states. Here we report an approach to controlling microflow patterns using an all-optical technique that should have broad applicability. In this approach the spreading of a micro-scale film on a solid substrate is both driven and controlled by surface tension gradients resulting from thermal absorption of light. The potential of this technique is demonstrated by experimentally measuring the dispersion relation for unstable contact lines and suppressing the instability using feedback control. These results suggest optical control may enable dynamically reprogrammable manipulations of fluid flow, thereby providing a new approach for constructing microfluidic devices analogous to CPUs in computers.

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## MS50

### Spatiotemporal Addressing of Surface Activity

Focusing an addressable laser beam to differentially heat a Pt single crystal surface, we have been able to modify the surface catalytic activity in real time and space. Ellipsomicroscopy imaging of local conditions (such as reactant and product local coverages) enables us to close the loop between sensing and actuation (both spatiotemporally resolved). I will show that pulses and fronts, the basic building blocks of patterns, can be formed, accelerated, modified, guided, and destroyed at will. Image processing and feedback allow the design and implementation of new classes of non-local evolution rules. Usually chemical processes are designed to operate under optimal steady-state conditions, possibly stabilized through feedback. Strategies to operate the entire process under non-steady-state (e.g., periodic) conditions are also being developed, leading to the emergence of commercially successful processes such as pressure swing operation or reverse flow reactors. In loose analogy with resonance in linear systems, the benefits

emerge when the characteristic times (periods) of the non-steady operation are close to important intrinsic time constants of the system itself. I will also show initial attempts to explore the optimization of reaction rates by interacting simultaneously with intrinsic system time and space scales. These policies are implemented on a Pt catalytic surface addressable through our moving, focused laser beam.

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### MS50

### Feedback Stabilization and Control of Unstable Propagating Waves

Unstable propagating waves are stabilized to a constant size and shape by applying negative feedback from the measured wave area to the excitability of the medium. The locus of steady-state wave size as a function of excitability defines the boundary for spiral wave behavior in active media. Intricate patterns of wave propagation are exhibited in a system with spatiotemporal feedback. Wave behavior is controlled by imposing feedback-regulated excitability gradients to guide propagation in specified directions. Waves interacting with boundaries and with other waves are observed when interaction terms are incorporated into the control algorithm. E. Mihaliuk, T. Sakurai, F. Chirila, and K. Showalter, "Feedback Stabilization of Unstable Waves," Phys. Rev. E 65, 656021-656024 (2002). T. Sakurai, E. Mihaliuk, F. Chirila, and K. Showalter, "Design and Control Patterns of Wave Propagation Patterns in Excitable Media," Science 296, 2009-2012 (2002).

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### MS50

### Spatial and Temporal Feedback Control of Benjamin-Feir Unstable Traveling Waves

We consider the effectiveness of spatially translated and time delay feedback control in stabilizing spatially periodic traveling wave solutions to the complex Ginzburg Landau equation in the Benjamin Feir unstable regime. We discuss an analytical stability criterion for determining the range of parameters over which the two feedback methods, applied simultaneously or separately, stabilize traveling waves. Extensions to two dimensions are discussed.

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### MS51

### Spiral Waves in Sequential Flames

Nonlinear dynamics of spiral waves on oscillatory combustion fronts is investigated. It is shown that this dynamics is described by complex Ginzburg-Landau or complex Swift-Hohenberg equations coupled to the equation for the Goldstone mode associated with the translation symmetry. Solutions of these equations are studies analytically and numerically and it is shown that the dynamics of spiral waves is strongly affected by the Goldstone mode.

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### MS51

### Counter-propagating Fronts in Pulsating Flames on an Annular Burner

I discuss the observation of counterpropagating fronts in pulsating premixed flame dynamics on an annular burner. A steady, premixed, annular flame bifurcates into counter-propagating fronts which collide in successively more complex patterns as the control parameter is varied. Periodic pulsations of small amplitude are replaced by more complicated dynamics: 1) in which the collision point varies; and 2) in which the flame front breaks up into both fronts and bright spots.

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### MS51

### Spatiotemporal Patterns and Dynamics of Hot Spots in Solid Fuel Combustion

We consider the gasless combustion model of the Self-Propagating High-Temperature Synthesis process in which combustion waves are employed to synthesize desired materials. We describe the appearance of hot spots in the propagating combustion wave and a variety of interesting complex spatiotemporal dynamics which they execute. In some cases we describe experimentally observed modes of propagation, while in others we predict new, as yet unobserved, modes of propagation.

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**MS51**

**Long-wave Dynamics of Flames Governed by Coupled Burgers Equations**

We investigate the stability of spatially-periodic waves governed by the system of coupled Burgers equations that describe, in the long-wave limit, oscillatory instability of a flame front in the presence of the Goldstone mode associated with translation symmetry. Linear stability analysis reveals the existence of two new types of modulational instabilities of traveling waves. The "Busse balloon" for spatially-periodic waves is absent, and only the homogeneous oscillations of the combustion front are stable. The nonlinear development of the instabilities is studied by numerical simulations.

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**MS52**

**A Perspective for Rigorous Large Scale Simulations of Turbulent Premixed Flames**

The flamelet regime of turbulent premixed combustion is by definition when both the reaction is much faster than the turbulence and the flame thickness is smaller than the Kolmogorov scale. The flame front is represented by a moving interface between burned and unburned gas. The principle role of turbulence, in this case, is to wrinkle the front and enhance the combustion speed at large scales. Through a simplified model, we introduce a new perspective for large eddy simulations of premixed flames using an asymptotic subgrid model. Numerical results are provided and unambiguous answers to some important practical ssues have been obtained. This is a joint work with Anne Bourlioux and Andrew J. Majda.

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**MS52**

**Propagation of Waves in a Turbulent Medium**

A multiscale flow field in the turbulent atmosphere gives rise to multiscale variation in the index of refraction. We consider a situation where waves propagate through a random medium with an index of refraction which exhibit multiscale variations. We examine how the shape and velocity of the propagating wave is affected by such medium heterogeneity. We also briefly discuss results from statistical analysis of physical measurements from the turbulent atmosphere with a view toward modeling of the random medium.

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**MS52**

**Rigorous Characterization of Boundary Layer Separations of 2D Incompressible Flows and its Applications to Geophysical Fluid Dynamics**

In this talk, I shall present a new dynamical systems theory of 2D incompressible flows, leading to a rigorous characterization of boundary layer separations. Topics to be addressed include a) structural bifurcation of 2D incompressible flows, b) characterization of boundary layer separations, c) adverse pressure gradient, d) boundary layer separations of the solutions of the Navier-Stokes equations and the quasi-geostrophic equations, and e) applications to Gulf stream separation. In additioon to the theoretical results, numerical simulations will be presented as well.

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**MS52**

**Regularity Results for Some Geophysical Models**

In this talk we will present some regularity results for linear problems related to the primitve equations of the ocean as well as global existence results for a two-layer geostrophic model.

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**MS53**

**Symplecticity Preserving Renormalization Group Method**

Abstract not available at time of publication.

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**MS53**

**Geometrical Formulation of the Renormalization-Group Method with Application to Transport and Stochastic Equations**

Abstract not available at time of publication.

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**MS53**

**Renormalization Group Approach to Differential**

**Equation Problems**

Abstract not available at time of publication.

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### MS53
### Title not available at time of publication

Abstract not available at time of publication.

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### MS54
### Bubble interaction in the stochastic Cahn-Hilliard equation

We discuss the problem of reduced asymptotic dynamics in gradient-type systems and their stochastic perturbations. We explain the general methodology and illustrate the technique on the example of stochastically perturbed gradient flows generated by the Ginzburg-Landau functional. In particular we provide a solution to the problem of bubble interaction in the one-dimensional stochastic Cahn-Hilliard equaion.

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### MS54
### Mean Field Descriptions of BEC: An Experimental Playground for Nonlinear Waves

The statistical description of bosons (well-) below the Bose-Einstein Condensation (BEC) temperature can be given by means of mean-field, nonlinear wave type models of the Gross-Pitaevskii type. Hence, it is natural to examine in this novel, experimentally tractable context much of the phenomenology that arises in spatially extended systems of the nonlinear Schrödinger type. In this talk, we revisit some of the important dynamical instabilities such as the modulational instability and the snaking instability, we study their manifestations in such BEC settings, as well as the coherent structures (such as solitons, soliton trains, vortices) to which they give rise. Comparisons with experimental results will also be presented.

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### MS54
### Effective Modeling in Complex Microfluid Systems

We apply a stochastic mode reduction method to obtain simplified equations for the dynamics of structures immersed in a thermally fluctuating fluid at low Kubo (or Reynolds) number under three different simulation approaches. Our primary focus is on the Immersed Boundary method of Peskin, though we also consider Brownian/Stokesian Dynamics and Dissipative Particle Dynamics schemes. The results are used to assist in the design and assessment of numerical simulations.

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### MS54
### Stochastic Mode-Reduction in Under-Resolved Systems

A recently developed theoretical framework for deriving a reduced set of stochastic differential equations from a complex nonlinear dynamical system with separation of time scales will be presented. In this procedure, reduced stochastic equations for a smaller collections of resolved variables are derived systematically for complex nonlinear systems with many degrees of freedom and a large collection of unresolved variables. This methodology is applied to developing coarse-grained models for prototype complex systems with many degrees of freedom utilizing the spectral truncation of the Burgers-Hopf equation as a nonlinear heat bath. Numerical simulations of original systems with 102 degrees of freedom are compared with simulations of the reduced equations for slow variables. Even for large value of the correlation time ratio of the order of one-half, the reduced stochastic model with two degrees of freedom captures the essentially nonlinear and non-Gaussian statistics of the original nonlinear systems extremely well. Furthermore it is demonstrated that the standard regression fitting of the second order correlations alone fails to reproduce the nonlinear stochastic dynamics in this example.

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### MS55
### Generic hydrodynamic instability via contact homology

It is a well-known fact among fluid dynamicists that hydrodynamic instability is "generic" for 3-d Eulerian (inviscid) fluids. However, it is very difficult to assign a meaning to "generic" which allows the statement to be proved. We use the geometry of the flow domain as a parameter and, using a criterion of Friedlander and Vishik, prove instability for generic geometry. This proof relies crucially on a new homology theory – contact homology – based on the work of Hofer on Hamiltonian dynamics.

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**MS55**

**Geometric realization of Pisot tiling spaces**

Pisot tiling spaces arise from substitutions over a finite alphabet whose associated homological action is represented by a Pisot matrix. It is conjectured that the translation action on such tiling spaces is measure theoretically isomorphic to a translation on a compact abelian group. In a joint work with Marcy Barge, we show that the conjecture is equivalent to a question about invertibility of a certain canonical map (geometric realization) from the tiling space to its associated group and can be reformulated as a "geometric coincidence conjecture" about the substitution. Geometric realizations and "coincidence conditions" have been already studied in this context by various authors and our main contribution is in providing a particularly natural and simple implementation of those ideas.

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**MS55**

**Recent results in the theory of compact minimal flows**

We discuss weak mixing, disjointness and regular almost periodicity of compact minimal flows in topological dynamics and give some applications of these notions to other areas.

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**MS55**

**Isolating Blocks for the Three-Body Problem**

Isolating blocks can be used to give a topological proof of the existence of orbits of the Newtonian three-body which are "captured into syzygy". This means that they are trapped near a collinear central configuration. These orbits actually form a separatrix in the integral manifold of the problem which contains them.

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**MS56**

**Probabilistic approach for designing synchronizing dynamical systems for parameter estimation**

Synchronization of a dynamical model with an experimentally measured time series may be used to estimate unknown parameters of the model. This can be done using an (external) optimization method that varies the parameters until a minimum of the synchronization error is achieved or with additional dynamical equations adjusting the unknown parameters. The latter approach is closely related to adaptive observers in control theory. We present a general method for designing synchronizing dynamical systems for parameter estimation that is based on approximations of the evolution of relevant probability density functions. Simulation results for different systems are presented.

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**MS56**

**Tuning Chaotic Synchronization for Application in Temporal Pattern Recognition**

Generalized chaotic synchronization phenomena have been proposed several times to be exploited for realizing associative memories and/or pattern recognizers. In particular, the selective properties of certain synchronization phenomena allows approximately periodic patterns to be tested against a chaotic dynamical system that is able to reproduce the class of time-series that is to be recognized. To exploit this selectiveness in concrete applications, the model has to be excited in a suitable way by the signal under test such that if the input signal belongs to the modeled class, the system approximately synchronize with it, if not, the trajectory of the system and the input signal remain unrelated. As presented here, this selectiveness can be suitably tuned relying on standard theories about periodic control theory and the corresponding robust filtering, i.e periodic Kalman filtering. O. De Feo gratefully acknowledges financial support from the Swiss National Science Foundation: FN-2000-63789.00; and from the European project APEREST: IST-2001-34893 and OFES-01.0456.

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**MS56**

**Using generalized synchronization for modelling and prediction of time series**

When a dynamical system drives another different system in a proper way, generalized synchronization occurs that is characterized by some nonlinear functional relation between the states of the coupled systems. We shall demonstrate how the resulting nonlinear functions may be used as building blocks for black-box modelling of (chaotic) time series. As a result we obtain discrete or continuous dynamical systems that are able to predict the future evolution of signals generated by some other dynamical system.

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### MS56

**Synchronization vs linear filtering for extracting phase information of oscillations of unknown origin from noisy time series.**

Oscillations are most naturally characterized by their phase dynamics (frequency). Complex-valued filtering can be used to extract unequivocal phase information from dirty, noisy, univariate signals. Here, the variance of the (normalized) magnitude squared of the filter output is used as a criterion to optimize these filters. Nonlinear and linear filters are compared. Some nonlinear filters oscillate autonomously for zero input. These are optimized to synchronize with the oscillation contained in the input signal.

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### MS57

**The Infancy of Fluid Flow Control Using Point Vortex Models**

The two-dimensional unsteady separated flow perpendicular to a flat plate is considered. The rolling-up of the separated shear layer is modeled by a pair of point vortices. A suction point located on the downstream side of the plate acts as an actuator. A nonlinear feedback controller able to confine the wake to a single vortex pair of constant circulation is derived in closed form.

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### MS57

**Extended Kalman Filtering for Vortex Systems**

We present the extended Kalman filtering for estimation of the flow dynamics induced by the point vortices. To estimate not only the vortices but also the background flow in which the vortices are embedded, we develop a variety of approaches. In particular, to incorporate the dynamical noises and observational errors with heavy-tail, non-normal distributions, we introduce the "extended Kalman-Levy filter." This work is in collaboration with C.K.R.T Jones, L. Kuznetsov, and D. Sornette.

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### MS57

**Assimilation of Tracer Data in Point Vortex Flows**

A stochastic point vortex system with a white Gaussian noise term added to represent unresolved processes is considered and tracked with a deterministic model that assimilates tracer positions observed at discrete times (Lagrangian drifter/float data). Difficulties in the assimilation of Lagrangian data arise because there is no direct connection between the instantaneous flow state variables and tracer observations that carry time-integrated information. A construction of an improved scheme that remains stable for high noise rates is presented. The successful performance of the above method in the case of this simple, but strongly nonlinear, system gives a favorable perspective on the possibility of applying it to realistic geophysical and engineering flows.

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### MS57

**Capillary Collapse and Pinchoff of a Soap-Film Bridge**

The dynamics of inviscid capillary breakup of a soapfilm bridge are investigated numerically and experimentally. The experiment consists of a soapfilm stretched between two coaxial rings that are slowly moved apart. At a critical separation distance the film loses its stability, collapses, and disconnects into a satellite bubble and two end pieces. Numerical simulations will be used to investigate whether properties of the resulting satellite bubble can be controlled by the boundary conditions.

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### MS57

**Pattern Observers and Feedback With Point Vortex Models**

Observers based on low order models are essential for an evolving feedback flow control theory. Traditional nonlinear state observers seem inappropriate for vortex models due to complexity and sensitivity. We explore the utilization of dominant coherent structures and periodicity of flows and actuation, as a substitute for state reconstruction. The talk reviews pattern-based observation and control for single and multiple vortex, as well as a novel Eulerian-vortex models for shear layer and recirculation dynamics.

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## MS57
## Optimal Control of Vortex Pairs

The problem of controlling the position of two point vortices using a strain field or a single source/sink is considered. The problem dimension is reduced by averaging the evolution equations over the rotation of vortices around the center of vorticity. We use Pontryagins maximum principle to show that for controls with bounded average magnitude the optimal solutions are impulsive: they consist of delta functions applied at optimal phases during the cycle of vortex rotation.

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## MS58
## The Bifurcation to Stochastic Chaos in a 3D Laser Model

We identify a global mechanism to induce chaos by stochastic perturbations in a three dimensional system. We have analyzed the transition matrix and transport between basins by approximating the stochastic Perron-Frobenius operator. This mechanism depends on both the standard deviation of the noise and the global topology of the system. We hypothesize that the noise facilitates dynamics that emulate a heteroclinic connection in the phase space, inducing chaotic behavior. Our particular application is geared towards the prediction and control of this emergent chaotic behavior.

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## MS58
## Mapping Transport Activity in Stochastic Dynamics, Directly from The Transfer Operator

Associated with a dynamical system, which evolves single initial conditions, the Frobenius-Perron operator evolves ensemble densities of initial conditions. We will present our new applications of this global and statistical point of view: Well-known models have been found to exhibit new and interesting dynamics under the addition of stochastic perturbations. Generalizing the Frobenius-Perron operator to stochastic dynamical systems, we develop new tools designed to predict the effects of noise and to pinpoint stochastic transport regions in phase space in the absence of global manifold information. We will also discuss the infinitesimal generator. We will identify a mechanism by which noise effectively completes the heteroclinic tangle, leading to bursting events. Physical applications will be discussed, including models from population dynamics and also a CO2 lasers.

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## MS58
## Noise-Induced Exit of Periodically Driven Systems: Scaling Crossovers

We discuss noise-induced escape from the attraction domain of a stable state of a periodically driven system. The strong dependence of the escape rate $W$ on the driving field enables selective control of the rate, important for many biological and physical applications. A general formulation of the escape problem in the presence of Gaussian noise will be outlined. We will then consider escape near a saddle-node bifurcation point of a driven system. The escape rate displays scaling behavior versus field amplitude $A$, with $\ln W \propto (A_c - A)^{\mu}$, where $A_c$ is the bifurcational value of $A$. For adiabatically slow modulation, i.e. for the modulation frequency $\omega_F \ll t_r^{-1}$ ($t_r$ is the relaxation time of the system) the exponent $\mu = 3/2$, as in the case of a static field. Since the system slows down as it approaches the bifurcation point, the adiabatic approximation breaks down, leading to a nonadiabatic scaling exponent $\mu = 2$. For still smaller $A_c - A$ the exponent changes to $\mu = 3/2$. The widths of different scaling regions strongly depend on the modulation frequency $\omega_F$. We will present experimental data and results from simulations and compare them with theoretical predictions.

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## MS58
## Noise Scaling of Statistical Averages in Chaotic Systems

We have identified a common situation in chaotic dynamical systems where statistical averages are affected by noise. A universal algebraic scaling law, which relates the variation of the statistical averages with the noise amplitude, is obtained in all dimensions. Our finding implies that shadowability of statistical averages cannot always be expected in chaotic systems.

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**MS58**

**Enhancing Spatial Coherence by Noise: A Spatial Analogue of Coherence Resonance**

It is well known that an optimal amount of random fluctuations can extract coherent behavior out of a nonlinear system, provided the system has an intrinsec time scale which can be excited by those fluctuations. We show that such coherence resonance has a purely spatial analogue, by which noise can extract spatial coherence out of extended nonlinear systems possessing an intrinsic length scale. We analyze the conditions under which such spatial coherence resonance occurs.

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**MS58**

**Stochastic Chaos Control-Theory and Applications**

Recent progress in the study of population dynamics has shown that external noise can influence the dynamics globally. Specifically, global changes observed in time series which form a distribution of large scale events, such as outbreaks in epidemics and intensity bursts in lasers, can be understood in a unified model consisting of a class of stochastic Hamiltonian systems. In this talk I will show how the dynamics of lasers and epidemics are not just similar locally, but have similar global topology, as well as similar global stochastic bifurcations. Such a theory allows for new methods of controlling stochastic chaos by using parametric methods to suppress large bursting events. Applications will be applied to a simple model of epidemic outbreaks which are induced by random perturbations.

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**MS59**

**Navier-Stokes-alpha Model and Boundary Layer Turbulence**

We study boundary layer turbulence using the Navier-Stokes-alpha model. It yields an extension of the Prandtl equations for the averaged flow in a turbulent boundary layer near a flat wall. In the case of a zero pressure gradient, those equations yield a nonlinear fifth-order ordinary differential equation, which is an extension of the Blasius equation. We present a mathematical study of this equation. Its solutions agree with experimental data in the transitional boundary layer, and in the turbulent boundary layer for moderately large Reynolds numbers.

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**MS59**

**Kraichnan Turbulence via Finite Time Averages**

Relations from Kraichnan's theory of fully developed two-dimensional turbulence are rigorously established for finite time averages. The averaging time is bounded in terms of the Grashof number, independent of the solution for which the time averages are taken. Other authors: Ciprian Foias, Oscar Manley

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**MS59**

**Parametrisation of Attractors and Takens Embedding Thereom**

We prove a general result showing that a finite-dimensional collection of smooth functions whose differences cannot vanish to infinite order can be distinguished by their values at a finite collection of points. This theorem is then applied to the global attractors of various dissipative parabolic partial differential equations, among them the Navier-Stokes equations with Dirichlet boundary conditions, and a reaction-diffusion equation with a $C^\infty$ nonlinearity. For the one-dimensional complex Ginzburg-Landau equation and for the 1d Kuramoto-Sivashinsky equation we show that a finite number of measurements at a very small number of points (two and four respectively) serve to distinguish between different elements of the attractor: this gives an infinite-dimensional version of the Takens time-delay embedding theorem.

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**MS59**

**Estimates for the Navier-Stokes Equations Pertain-**

**ing to the Statistical Theory of 3D Stationary Turbulence**

We present some rigorous results on the Navier-Stokes equations connected with the conventional theory of turbulence. Such results are based on the concept of stationary statistical solution, which is an extension of an invariant probability measure and which makes rigorous the notion of ensemble average for turbulence in statistical equilibrium. With this concept at hand we derive estimates relating several physical quantities relevant to turbulence theory. In particular, we discuss the mean kinetic energy flux and conditions for the existence of an energy cascade.

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**MS59**

**Adjoint-based Iterative Methods for Robust Control in Fluid Mechanics: Application to Data Assimilation in Oceanography**

We study the convergence of an adjoint-based iterative method proposed by Bewley, Temam and Ziane for the numerical solutions of a class of nonlinear robust control problems in fluid mechanics. We prove the convergence of the algorithms and we obtain an estimate of the convergence rate. Numerical solutions of a robust control problem related to data assimilation in oceanography is given to illustrate the method.

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**MS59**

**Emergence of Large Scale Structure Under Small Scale Random Forcing**

In this talk we present partial justification of the numerical observed emergence of large scale structure in 2D viscous flows driven by small scale random bombardments. The justifications are in terms of estimates on the Dirichlet quotient of the velocity field, and existence of certain invariant measures. This is a joint work with Andrew Majda of New York University.

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**MS60**

**Basics of Canards**

As an introduction to the mini-symposium, the basics of the canard phenomenon is outlined. Possible mathematical approches, nonstandard analysis, perturbation methods, and invariant manifold theory are reviewed. We turn to the wide range of applications, spanning from mechancial engineering to chemistry, biology, and economics, and discuss a large class of systems where canards can be expected, and connect canards to bifurcations at infinity.

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**MS60**

**Canard Explosion and Canard Chaos**

In this talk we consider generalizations of canard explosion to systems with more than one slow variable. We present criteria for determining if the generalized canard explosion is chaotic or regular (consists of transitions from small oscillations to relaxation oscillations, through a sequence of canard cycles). We also explain the simplest mechanism of a chaotic canard explosion (canard chaos).

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**MS60**

**Canards in a Surface Oxidation Reaction**

Canards are shown to occur in an appropriate parameter range in two- and three-dimensional models of the platinum-catalyzed oxidation of carbon monoxide. By smoothly connecting associated stable and unstable manifolds in an asymptotic limit, parameter values at which such canards exist are predicted. The relationship between the canards and saddle loop bifurcations for these models is also demonstrated. Excellent agreement is found between numerical and analytical results.

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**MS60**

**Canards in the Schroedinger Equation**

The eigenvalue-problem for the one-dimensional Schroedinger equation with single and double well potentials is considered in the semiclassical limit. Eigenfunctions for the Schroedinger equation correspond to canard solutions of the associated singularly perturbed Riccati equation, which can be treated in the framework of geometric singular perturbation theory. For eigenvalues close to the bottom of the well the corresponding slow manifolds intersect in a transcritical bifurcation in the singular limit. Based on the recently developed blow-up method low-lying eigenvalues are analysed geometrically. This approach leads to a new proof of the exponentially small splitting of the lowest eigenvalues for symmetric double well potentials.

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**MS60**

**Canards in Systems with 2-d Folded Critical Manifold**

We give a geometric analysis of canard solutions in singularly perturbed systems with two-dimensional folded critical manifold. Under the violation of a certain transversality condition singular canards are detected in the reduced system near isolated points of the fold-curve. These canard

points are classified in correspondence with the phase portrait of the reduced flow nearby as folded saddles, folded nodes and folded saddle-nodes. Based on the blow-up technique the existence of canards in the case of folded saddles and folded saddle-nodes is proved. Furthermore it is shown that bifurcations of canards occur in the case of folded nodes. We give applications arising in chemical, physical and neuronal problems where these canards are detected and show how they are involved in more complicated global bifurcations.

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### MS60

### Canards and Chaos in the Forced Van der Pol Equation

Cartwright and Littlewood discovered "chaotic" solutions in the periodically forced van der Pol equation in the 1940's. Subsequent work by Levinson, Levi, and others has made this singularly perturbed system one of the archetypical dissipative systems with chaotic dynamics. Despite the extensive history of this system, many questions concerning its bifurcations and chaotic dynamics remain. We use a combination of analysis of the singular limit and numerical simulation to investigate the bifurcations of this system. In particular, we give a clear picture of a horseshoe map that arises in a cross-section of the three-dimensional phase space. The canards that form at a "folded saddle" play a crucial role in this analysis. (This is joint work with John Guckenheimer and Kathleen Hoffman. Part of this research was also done by a group of undergraduates during an REU program at Cornell University in the summer of 2002.)

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### MS61

### On the Identification of Macroscopic Dynamics

*Almost invariant sets* are regions in phase space for which there is a small probability that trajectories entering such a subset will leave that subset in a short period of time. Thus, these subsets define *macroscopic structures* preserved by the dynamical process. Almost invariant sets can be identified in two steps: first the dynamical behavior is approximated by a Markov chain; second the detection of almost invariant sets is done by finding minimal cuts in the associated graph. In this talk we will discuss different graph theoretic approaches for solving this optimization problem. The algorithms are illustrated by the identification of transport phenomena for asteroids in the solar system.

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### MS61

### Coarse Control and Coarse Optimal Paths for Microscopic/Stochastic Simulators

Using the so-called coarse timestepper approach to microscopic/stochastic simulators, we perform the coarse stability/bifurcation analysis of closed equations for moments of evolving distributions without explicitly obtaining these equations. The stationary states and their coarse Jacobians are then used for the design of coarse observers and controllers, as well as for the formulation and solution of coarse optimization problems (including optimal path computation in moments space). Applications to kinetic Monte Carlo as well as Brownian Dynamics simulations are presented.

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### MS61

### Model Reduction in Mechanical Models of Heat Baths

We study large mechanical systems with random initial data, modelling a particle interacting with a "heat bath". In the limit where the number of particles in the heat bath tends to infinity, it may be possible to approximate the trajectory of the distinguished particle by the solution of a Markovian SDE. I will present a combination of rigorous convergence results, along with more speculative results, reinforced by a numerical validation.

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### MS61

### Reduction and Reconstruction for Self-similar Dynamical Systems

We present a general method for analyzing and numerically solving partial differential equations with self-similar solutions. The method employs ideas from symmetry reduction in geometric mechanics, and involves separating the dynamics on the shape space (which determines the overall shape of the solution) from those on the group space (which determines the size and scale of the solution). The method is computationally tractable as well, allowing one to compute self-similar solutions by evolving a dynamical system to a steady state, in a scaled reference frame where the self similarity has been factored out. More generally, bifurcation techniques can be used to find self-similar solutions, and determine their behavior as parameters in the

equations are varied. The method is given for an arbitrary Lie group, providing equations for the dynamics on the reduced space, for reconstructing the full dynamics, and for determining the resulting scaling laws for self-similar solutions. We illustrate the technique with a numerical example, computing self-similar solutions of the Burgers equation. This work is related to previous work on the POD, or Karhunen-Loeve, model reduction method for systems with symmetry: Rowley, C. W. and J. E. Marsden [2000], Reconstruction equations and the Karhunen-Love expansion for systems with symmetry, *Phys. D*, **142**, 1-19. Based on work of Clancy Rowley, Ioannis Kevrekidis, Kurt Lust and the speaker.

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### MS61

### Dimensional Reduction and Spectral Properties of the Koopman Operator

We present a study of the Proper Orthogonal Decomposition technique from the perspective of spectral theory of dynamical systems. It is shown that spectral properties of the so-called Koopman operator can be translated into a new kind of a decomposition that we call the Mixed Orthogonal Decomposition. This new decomposition separates periodic, predictable part of the dynamics from the aperiodic, stochastic part that is treated using the standard Proper Orthogonal Decomposition.

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### MS61

### Model Reduction, Coarse Graining, and the Renormalization Group

We rigorously establish what type of coarse grainings are appropriate for systems with quadratic Hamiltonians using standard Hankel norm model reduction techniques. The novelty of this approach is that it dictates how a system should be coarse grained regardless of whether the system is isotropic or not. Additionally, these techniques can be easily sythesized with the renormalization group (RG) from physics. This approach leads to the investigation of the Perron-Frobenius operator associated to the (spatial) coarse graining of the system as opposed to its dynamics. Invariant densities of the above operator then correspond to particularly interesting reductions.

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### MS62

### Geometric Particle-mesh Methods for Geophysical Fluid Dynamics

Of primary interest in atmospheric and oceanic fluids are potential vorticity conservation, energy conservation, and balance. These concepts have a rich variational structure which we attempt to reproduce in a numerical particle-mesh method. The method is Hamiltonian and conserves circulation in an interpolated velocity field. Recent developments and will be discussed including numerical experiments.

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### MS62

### A Discrete-Time Formulation of Hamiltonian Mechanics

We construct a Hamiltonian formulation of discrete-time mechanics. The dynamics are shown to be related to those of symplectic integrators constructed via variational techniques from a discretized version of the Hamilton principle. The approach allows us to relate the generating functions used in continuous-time Lagrangian mechanics to corresponding objects in the Hamiltonian formulation. We also discuss possible generalizations and the use of these methods for numerical schemes.

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### MS62

### Bridging Time Scales in Structural Mechanics: Asynchronous Variational Integrators

We describe a class of asynchronous variational integrators (AVI) for nonlinear elastodynamics. The AVIs are characterized by the following distinguishing attributes:

1. The algorithms permit the selection of independent time steps in each element, and the local time steps need not bear an integral relation to each other;
2. the algorithms derive from a discrete version of Hamilton's principle. As a consequence of this variational structure, the algorithms conserve linear and angular momentum exactly.

Numerical tests reveal that energy is also conserved, a property which can probably be traced to the symplectic nature of the algorithm. The remarkable computational

savings stemming from the asynchronous updates are illustrated through the simulation of the dynamics of a helicopter rotor blade.

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## MS62
### On the Algebraic Structure of Lie-Butcher Series

The theory of order conditions for Runge-Kutta RK-methods was developed by John Butcher in his seminal Butcher theory describes the algebraic structure of Runge-Kutta methods. Recently Connes and Kreimer developed a Hopf algebraic approach to renormalization theory, shown by Brouder to be equivalent to Butcher theory. Chen-Fliess series are similar tools in non-linear control. Lie Group Integrators are canonical Runge-Kutta methods on manifolds, whose order theory involves extension of (commutative) Butcher theory to non-commutative flows on manifolds. We present new results on the Hopf algebraic structure of LGI, and relations to the other theories.

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## MS62
### Multidimensional Consistency of Discrete Equations as the Fundamental Integrability Principle

We discuss a recently developed approach to the integrability of discrete systems. In this approach, the integrability of a d-dimensional system is associated with the consistency of a $(d+1)$-dimensional one, where the original system is imposed on all $d$-dimensional sublattices. It is demonstrated that for $d = 2$ this definition automatically leads to an algorithmic construction of the discrete zero-curvature representation of the original system. Moreover, it can be used to solve the classification problem (to list all integrable systems satisfying certain ansatz). Such a classification was achieved for one-field systems on quad-graphs, i.e. on planar graphs with quadrilateral facets. Various generalizations of these results will also be discussed.

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## MS62
### Geometric Integrators for Non-smooth Collisions

Mechanical systems with collisions pose a number of problems for standard theoretical and numerical techniques due to their extremely nonsmooth behavior. In this talk we formulate variational collision problems in both continuous and discrete time. This yields an interesting class of integrators which preserve well-defined geometric structures from the continuous time problem. We use these as a basis to construct a highly efficient explicit collision algorithm, which we demonstrate on a thin-shell collision problem.

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## MS63
### Insights into DNA folding from elastic rod theory

DNA is known to adopt a series of folded structures within the cell nucleus. Utilizing experimentally determined elastic constants for linear DNA and a simple fold geometry we derive elastic constants for extended and condensed chromatin. Results are in good agreement with experimental values and indicate that folding not only affects a compaction of DNA but also affects the time scale for dynamics at each level of folding.

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## MS63
### Theory of sequence-dependent DNA elasticity

A summary will be given of the recent research at Rutgers on a theory of DNA elasticity that takes into account the dependence of the elastic properties of DNA on nucleotide sequence. Among the topics to be discussed are models for action at a distance in gene regulation, and calculations, by Y. Biton, B.D. Coleman, and D. Swigon, showing a strong dependence of minimal energy configurations of intrinsically curved DNA on the concentration of salt in the medium.

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## MS63
### Experimental and Computational Studies of DNA Minicircles

In covalently closed DNA molecules changes in local helical structure are tightly coupled with changes in global tertiary structure. An abundance of biological examples of this coupling exist such as cruciform extrusion, triple-helix formation, the B-Z transition, and unwinding at promoter sequences. Large plasmid-sized DNA molecules, which are in the range of several thousand base pairs, have significant limitations in terms of experimental studies of local sequence-dependent effects. We are addressing some limitations of plasmid systems by studying conformational transitions in small circular DNAs, 100-200 base pairs in size. An efficient method for preparing DNA minicircles via site-specific recombination will be described. The thermodynamics of DNA cyclization as investigated by Monte

Carlo simulation methods will also be discussed.

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### MS63

### Sensitivity of DNA minicircle energies to several shape and flexibility parameters

DNA cyclization experiments have been used as experimental probes for various mechanical properties of DNA, including intrinsic bending, intrinsic twist, and bend and twist flexibilities. An ensemble of DNA molecules with similar lengths and base-pair sequences is constructed, their cyclization energies determined experimentally, and then some mechanicasl model is applied for the purposes of fitting these shape and flexibility parameters We investigate which of these parameters affect most sensitively the cyclization energies, using an elastic rod model applied to data from experiments by Jason Kahn on several protein-binding sites and sequences of apparently high intrinsic bending or flexibility. For those parameters yielding sufficiently large sensitivity with respect to the level of uncertainty in the experiments, we extract ranges of parameter values consistent with the experimental results.

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### MS63

### Control of transcription by DNA looping

A recently developed theory of sequence-dependent DNA elasticity has been employed to calculate the structure and dynamics of a protein-DNA complex arising during initiation of transcription of the *lacZYA* genes in *E. coli.* That complex contains a DNA loop that is formed by the binding of the Lac repressor to its operator sites in the promoter region. Calculations of the effect of the loop on activation and repression of *lacZYA* genes suggest general principles for the dependence of gene regulation on promoter architecture.

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### MS63

### DNA Minicircles: Comparison of Mechanical and Statistical Mechanical Analysis

Large DNA molecules adopt enormous number of different conformations and proper analysis of their properties requires statistical mechanical treatment. In contrast to this, conformations of small DNA circles correspond to a relatively narrow set. Can we use only minimum energy conformations to calculate experimentally observable properties of such small circles? We analyzed the issue by direct evaluation of a few conformational properties of the circles, both in terms of energy minimization and statistical mechanical analysis.

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### MS64

### Mapping Dynamics of Coupled Nonlinear Neural Oscillators: Effects of Strong Coupling

Network dynamics of model stellate neurons can change considerably when the strength of coupling is increased. Many of these changes can accurately be captured using the Spike Time Response (STR) method, which generates a one-dimensional map describing two-cell network dynamics. Strong coupling often causes cycle-skipping, where a cell skips a beat in response to an excitatory input. When the model includes a large, slow conductance, even tiny inputs can produce large responses and can even elicit cycle-skipping. In this case, we propose that the model is more sensitive to inputs due to a reduction in the "attractiveness" of the spiking limit cycle.

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### MS64

### Multiple Scale Analysis and Local Models Generate Low-dimensional Maps

We consider a high-dimensional model of a biophysical neural network, that posesses a low-dimensional attractor (e.g. synchrony). We discuss a method which reduces the study of the system near the attractor to the analysis of a set of 'local' low-dimensional models (particularly maps), according to multiple scales of time and interaction, in the differential equations. This technique adds rigour to an intuitive reduction technique [1], aiding the quantification of robustness and parametric dependence in characterising coherent activity. [1] Ermentrout, G.B., and Kopell, N.

(1998) *Proc. Natl. Acad. Sci. USA*, 95:1259-1264

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### MS64
### The Virtues of Being Slow

Synapses that rise quickly but have long persistence are shown to have certain computational advantages. They have some unique mathematical properties as well and can in some instances make neurons behave as if they are weakly coupled. This latter property allows us to determine their synchronization properties. Furthermore, they allow recurrent networks to maintain excitation in absence of inputs whereas faster decaying synapses prevent recurrent excitation. There is an interaction between the synaptic strength and the persistence which allows recurrent networks to fire at low rates if the synapses are sufficiently slow. These ideas lie at the biophysical basis for persistent activity observed in both cortical slice preparations and in *in vivo* preparations.

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### MS64
### The Existence and Stability of Phase-locked States in Coupled Phase Response Curves

Repetitive firing of action potentials is a prominent mode of activity in neurons. In such a system with a strongly attracting limit cycle, a "synaptic input" can be qualitatively captured in a perturbation in its phase. We study nontrivial firing patterns in small assemblies of pulse-coupled oscillatory maps. We find conditions for the existence of waves in rings of coupled maps that are coupled bidirectionally. We also find conditions for stable synchrony in general all-to-all coupled oscillators. Surprisingly, we find that for maps that are derived from physiological data, the stability of synchrony depends on the number of oscillators. We describe rotating waves in two-dimensional lattices of maps and reduce their existence to a reduced system of algebraic equations which are solved numerically.

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### MS64
### Scale-up for Cortical Modelling

In this lecture, I will describe coarse-grained asymptotic methods designed to scale-up models of the primary visual cortex. These methods will include coarse grained representations for mean firing rates, probability density function representations of voltages and conductances, and embedded point neuron representations. The latter consists in a network of point neurons, embedded in and fully interacting with, a coarse grained representation of local neuronal behavior.

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### MS64
### Epilepsy in Small-World Networks

Models of epilepsy originating from the hippocampus region of the brain have demonstrated two principle behaviors – bursting and seizing. Typically, bursts originate from the CA3 region of the hippocampus, and seizures from the CA1 region. A notable anatomical difference between these regions is that CA1 has few recurrent connections, while the CA3 has approximately 3% probability of any two randomly selected cells in the region being connected. Our hypothesis is that these behaviors can be attributed mainly to the connectivity of the network. We have built network models incorporating different amounts of physiological detail, and measured changes in the dynamics of the cell population as the connectivity is changed. Network connectivity in all the models is based on Small World Networks. These models were further reduced to a probabilistic model of seizure generation and propagation. Using this reduction we can explicitly derive an anatomical condition which predicts whether a network will burst or seize.

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### MS65
### Turbulent Entrainment in the Upper Layer of an Ocean Fish-tank

We examine entrainment effects from a lower layer of heavy (salt) water due to the turbulent flow generated by an array of jets at an upper layer of lower density brine. The motivation for this experiment comes from the dynamics of the mixed layer of the upper ocean,which can experience episodes of rapid evolution under intense wind driven turbulence. The water is contained in a large fish-tank, and stratification is created initially by laying fresh water on top of brine. In order to explore different turbulent patterns, various configurations of jets and their speeds are used at lateral boundaries. By collecting the overflow from the tank, salinity, and hence entrainment from the lower deep layer, can be monitored vs. time and related to the energy budget and configuration parameters.

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### MS65
### Polymorphic Flagella and Coiling Fluid Jets: Heli-

**cal Dynamics in Biology and Physics**

The cellular locomotion that underlies bacterial chemotaxis is characterized by stochastic transitions between straight-line swimming and reorientations, triggered by reversals of the rotary motors that turn multiple helical flagella. These reversals may also trigger chirality reversals of the flagella themselves, through a remarkable process of front propagation, and isolated flagella held in external fluid flows may also undergo periodic chirality transitions. This talk will focus on an explanation [1] for these phenomena based on the underlying multistability of the flagellar morphologies and their interaction with external flow fields. Also described will be an experiment under development* to test these theoretical predictions and related aspects of biological fluid dynamics, particularly the interaction between flexible helical objects in low Reynolds number flow. In the latter context, some related experiments and theory will be described on helical instabilities, entrainment, and synchronization of viscous fluid jets decelerated by passage through stratified surrounds.

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### MS65

### Experiments from your Backyard: Tendril Perversion and Twining Vines

One of the most fascinating aspects of growth in plants is found in the movements and habits of climbing plants. Climbing plants are not self-supporting, tand they use their surrounding to achieve vertical growth. In this talk, I will discuss and model two different strategies used by vines to grow: the twiners and the tendril-bearers. Twiners grow in a helical manner around poles and the tendril-bearers use modified leaves to pull themselves upwards. These two systems lead to interesting dynamical systems models and relatively easy experiments.

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### MS65

### Stability Webs in Hill's Equations

We describe an interesting web-like structure of the stability diagram of Hill's equation. This structure does not arise in the well-known Mathieu equation, whose potential contains only one harmonic. An observation of this web-like structure led to the discovery of a certain isochronous property of trigonometic potentials. Joint work with Carles Simo and Henk Broer.

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### MS65

### An Internal Splash: Falling Spheres in Stratified Fluids

We experimentally explore the motion of falling spheres in strongly stratified fluids and document a non-monotonic sphere velocity profile connecting the maximum and minimum terminal velociites. Moreover, we document an internal splash in which the falling sphere may actually reverse its direction of motion as it penetrates a region of strong density transition. We give a physical explanation of this motion which necessarily couples the sphere motion with the stratified fluid, and vice versa, and supplement this with a simplified, reduced mathematical model involving a nonlinear system of ordinary differential equations which captures the non-monotonic transition, and offers a means to quantify entrainment and mixing in stratified fluids.

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### MS65

### Playful Boundary in Moving Fluids: Experimental Studies on Flexible Structures in Fluid Flows

Trees bend in a strong wind. Parachutes open as they fall from the sky. Fish swim with ease. Hearts pump blood to support life. In nature, we have countless examples where fluid flows interact with deformable structures. Understanding how deformable structures interact with fluids is a problem of great interest, both in terms of fundamental research in fluid dynamics and for its many industrial applications. Flexible bodies can be deformed by the surrounding fluid forces. A natural question is how drag changes in response to such deformation. In this talk, I will focus on a few prototype problems, walking through experiments, to show that in most cases drag can be significantly reduced due to flexibility. Such examples can be found with broad tree leaves in high wind and swimming fish cruising at high speed. In other cases, drag increases with flexible structures – such as a flapping flag and a falling parachute.

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### MS66

### Traveling Waves for a Bistable Equation with Nonlocal and Indefinite Interaction

Mathematical models for neural networks and phase transitions in material science include spatially long-range interaction between neurons or particles, in the case of materials. Some of the interaction effects are inhibitory (or anti-ferromagnetic) and some are excitatory (ferromagnetic). This leads to evolution equations of the form du/dt = r(J*u -u) +f(u), (NAC), where r ¿0 is a parameter, * means spatial convolution (discrete or continuous), J is a kernel that changes sign, u(x,t) is the state of the system at position x and time t, and f is a bistable nonlinearity. In the discrete case, this equation also arises from the method of lines treatment of a reaction diffusion equation, but in that case J is non-negative. In the case of J being nonnegative, a comparison principle holds and traveling waves for (NAC) may be found by monotonicity and continuation methods.

In the case at hand, with J changing sign, there is no comparison principle for (NAC) and other methods must be employed. In the case that f is not balanced, we use a perturbation argument and spectral analysis to obtain a traveling wave for r sufficiently small. When f is balanced, variational methods are used to obtain a stationary wave for any r¿0. This is joint work with Xinfu Chen and Adam Chmaj.

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**MS66**

**Stabilization of Bumps by Noise**

Including spike frequency adaptation in the neural dynamics of a network supporting a "bump" of active neurons causes the stationary bump to become unstable to a moving bump. Adding spatiotemporal noise can cause the average speed of the bump to decrease to almost zero, "restabilizing" the bump. This can be understood by examining the effects of noise on the normal form of a pitchfork bifurcation. This noise-induced stabilization is a novel example in which moderate amounts of noise have a beneficial effect on a system.

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**MS66**

**Localized Pattern Formation Without Recurrent Excitation**

In neuronal networks, synaptic coupling between cells is spatially nonlocal and temporally dynamic. As in excitable media, localized, sustained activity may develop when neurons are connected with an appropriate combination of short-range, or recurrent, excitation and long-range inhibition. In this talk, I will present mathematical results on the development of localized, sustained activity in the absence of recurrent excitation, motivated by experiments on networks in which it is absent. The models under consideration consist of networks of differential and integrodifferential equations for excitatory and inhibitory populations of neurons, coupled synaptically.

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**MS66**

**The Evans Function for Equations with Nonlocal Terms**

In recent studies of the master mode-locking equation, a model for solid-state cavity laser that includes nonlocal terms, bifurcations from stationary to seemingly time-periodic solitary waves have been observed. To decide whether the mechanism is a Hopf bifurcation or a bifurcation from the essential spectrum, we show that and how the Evans function can be constructed for a large class of equations with nonlocal terms. The theory is then applied to the master mode-locking model.

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**MS66**

**Spatial Symmetry Breaking with Light-Induced Remote Communication**

Domains containing spiral waves form on a stationary background in a photosensitive Belousov-Zhabotinsky reaction with light-induced nonlocal feedback. Complex behavior of colliding and splitting wave fragments is found with feedback radii comparable to the spiral wave length. A linear stability analysis of the uniform stationary states in an Oregonator model reveals a spatial symmetry breaking instability. Numerical simulations show behavior in agreement with that found experimentally and also predict a variety of other new patterns.

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**MS67**

**Stabilization by Diffusion in a Coupled Ginzburg-Landau Equation**

We consider a system of a Ginzburg-Landau equation coupled to a reaction-diffusion equation with slow diffusion. Such a coupled system naturally arises as modulation equations in various applications. We show that this system has a traveling single pulse solution with a unique wave speed determined by the parameters. This solution mimicks the (unstable) stationary single pulse pattern in the original Ginzburg-Landau equation. The key question we address, is whether this pulse solution can be stabilized by the coupling to the slowly diffusing second equation.

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**MS67**

**Destabilization of Fronts in a Class of Bi-Stable Systems**

We consider a class of bi-stable reaction-diffusion equations in two components on the real line. This class admits front solutions that are asymptotically close to the (stable) front solution of the 'trivial' scalar bi-stable limit

system $u_t = u_{xx} + u(1 - u^2)$. However, in the system these fronts can become unstable by varying parameters. This destabilization is either caused by the essential spectrum or by an eigenvalue that exists near the essential spectrum. We use the Evans function to study the various bifurcation mechanisms.

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### MS67

### The Eigenvalue Problem for Perturbed Integrable Systems

Consider an integrable PDE in which the underlying scattering problem is the generalized Zakharov-Shabat spectral problem related to a given semisimple Lie algebra. When studying the linear stability of waves for small perturbations of such a system, a fundamental problem is the location of the point spectrum of the linearized operator. Upon perturbation, eigenvalues near the continuous spectrum may be created via an edge bifurcation. This bifurcation is nonstandard, as the eigenfunctions associated with the eigenvalues may initially not be localized. In joint work with B. Sandstede, we show how the Evans function can be used to not only detect those points in the continuous spectrum at which an edge bifurcation can occur, but also to give a strict upper bound on the possible number of bifurcating eigenvalues.

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### MS67

### On a Stable Double Heteroclinic Loop Pulse of Saddle-Focus Type

Double heteroclinic loop pulse of "saddle-focus" type has been regarded as an unstable object, in fact it was shown rigorously that such a pulse is unstable for 2x2 system under natural conditions, however, for 3x3 systems, we found that stable one exists and it is closely related to what is called transient instability. Such a pulse is believed to play an important role to detect the onset of spatial-temporal complex patterns.

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### MS67

### Travelling Waves in a Singularly Perturbed Sine-Gordon Equation

We determine the linearised stability of travelling front solutions of a perturbed sine-Gordon equation. This equation models the long Josephson junction using the RCSJ model for currents across the junction and includes surface resistance for currents along the junction. The travelling waves correspond to the socalled fluxons and their linear stability is determined by calculating the Evans function. Surface resistance corresponds to a singular perturbation term in the governing equation, which specifically complicates the computation of the corresponding Evans function. Both the flow of quasi-particles across and along the junction stabilise the waves.

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### MS68

### On the Computation Nonsmooth Center Manifolds

An algorithm for computing inertial manifolds is adapted for center manifolds. It is applicable in the case of a nonsmooth vector field, and most appropriate when the manifold is desired along trajectories only, as opposed to in its entirety. Its performance is demonstrated on several test cases. We also discuss a reformulation of the original algorithm for inertial manifolds which results in significant saving in computational effort for both that and the center manifold case.

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### MS68

### A Set Oriented Approach to the Computation of Invariant Manifolds

One way to approximate an invariant manifold is to compute a covering of it, consisting of a finite number of "simple" sets. In this talk we describe continuation algorithms that construct such coverings and state results about their convergence. We outline details of their implementation and present a couple of numerical examples. The advantage of these algorithms is threefold: they are readily capable to compute manifolds of arbitrary dimension, they are robust with respect to the geometry of the computed manifold and, finally, their output enables a postprocessing in form of a statistical analysis of the dynamics on the invariant manifold.

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## MS68
### Manifolds in the Lorenz System

The two-dimensional global stable manifold of the origin in the Lorenz system is challenging, both as a geometric object as well as a computational problem. We will discuss the computation of this manifold as a collection of levelsets, defined as the sets of points with equal geodesic distances to the equilibrium (along the manifold). We then show some new ideas that are useful when visualising the manifold and display its complicated geometry.

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## MS68
### Ordered Upwind Methods for the Invariant Manifolds

We show how the problem of constructing an invariant manifold (of co-dimension k) can be locally reduced to solving a (system of k) quasi-linear PDE(s), which can be solved very efficiently using Ordered Upwind Method (OUM). Such methods, originally introduced in a joint work with J.A. Sethian for static Hamilton-Jacobi PDEs, rely on careful use of the direction of information propagation to systematically advance the computed "boundary" and to de-couple the discretized system. We illustrate our approach by constructing stable and unstable manifolds of saddle points for several dynamical systems with multiple time-scales.

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## MS69
### A Unified Prediction of Computer Virus Spread in Connected Networks

We derive two models of viral epidemiology on connected networks and compare results to simulations. The differential equation model easily predicts the expected long term behavior by defining a boundary between survival and extinction regions. The discrete Markov model captures the short term behavior dependent on initial conditions, providing extinction probabilities and the fluctuations around the expected behavior. These analysis techniques provide new insight on the persistence of computer viruses and what strategies should be devised for their control.

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## MS69
### Evolving Networks with Multispecies Nodes and Spread in the Number of Initial Links

We consider models for growing networks incorporating two effects not previously considered: (i) different species of nodes, with each species having different properties (such as different attachment probabilities to other node species) and (ii) when a new node is created, its number of links to old nodes is random with a given probability distribution. Our numerical simulations show good agreement with analytic solutions. As an application of our model, we investigate the movie-actor network with movies considered as nodes and actors as links.

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## MS69
### Epidemic Processes on Networks

The spread of a disease is heavily influenced by the structure of the contact network over which it is communicated. Recent studies have revealed two important features of contact networks that have been absent from previous epidemiological work, namely heavily right-skewed degree sequences, and vertex-vertex degree correlations. We describe solutions of some general models of disease spreading on networks with these features, making use of an exact mapping to bond percolation and generating function methods. The results demonstrate the particular importance of core groups and high-activity individuals within contact networks.

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## MS69
### Heterogeneity in Oscillator Networks: Are Smaller Worlds Easier to Synchronize?

Small-world networks are known to be more easily synchronized than regular lattices, which is usually attributed to the smaller network distance between oscillators. Surprisingly, we show that networks with homogeneous distribution of connectivity are more synchronizable than heterogeneous ones (e.g., scale-free networks), even though the average network distance is larger. Some degree of homogeneity is then expected in naturally evolved structures, such as neural networks, where synchronizability is desirable.

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**MS70**

### Stochastic Dynamics of Chemotaxis: Beyond the Keller-Segel Equations

We consider a discrete model of chemotaxis formulated as a stochastic differential equation. By considering multivariate probability distributions of the cell positions we are able to derive the hierarchy of equations satisfied by these functions. The lowest-order truncation scheme when applied to this hierarchy yields the Keller-Segel equations. We discuss extensions to Keller-Segel that arise from more sophisticated truncation schemes. We also discuss various simulation models which are approximately described by our stochastic differential equation. These simulation models display rich and sometimes counter-intuitive dynamics, which we attempt to explain in terms of anomalous random walks.

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**MS70**

### From Signal Detection to Behavioral Response: An Integrated Model for Bacterial Chemotaxis

Recent experimental and theoretical work has brought us quite close to a complete computational model for signal transduction and motor control in bacterial chemotaxis. In this talk we will discuss recent theoretical progress on understanding the locus of high gain in E. coli, we will describe a cell-level model that incorporates the entire signal transduction and motor control pathway, and we will introduce an efficient computational scheme in which the model for the microscopic evolution is embedded in a macroscopic time-stepper.

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**MS70**

### Modelling Micro to Macro in Chemotaxis and its Role in Development

Modelling chemotactic movement requires the integration of events occurring at a variety of levels. Here we will discuss the development of macroscopic models of chemotaxis from the underlying microscopic aspects of cell signalling and movement. We consider a number of applications in embryonic development, including the model of cell movement through tissues and the formation of pigment stripes on fish.

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**MS70**

### On the Relation Between Kinetic Transport Models and Fluid Models for Chemotaxis

In many situations the observed chemosensitive movement of cells ('run and tumble') lends itself naturally to a kinetic description. The cells are modelled by a distribution in phase (i.e., position and velocity) space subject to free streaming and to scattering events, described by transition probabilities for velocity jumps. Microscopic information on individual cell behaviour enters the model via these transition probabilities. A standard model reduction approach in kinetic theory is the macroscopic limit leading to fluid models for a finite number of macroscopic quantities depending only on position. Results on a rigorous justification of the macroscopic limit will be presented, when the kinetic equation is nonlinearly coupled to an equation for the production of the chemoattractant. Here blow-up or non-blow-up for the kinetic and/or macroscopic models is an interesting issue. The class of macroscopic models considered includes the classical Patlak-Keller-Segel model. This modelling approach can be used for testing hypotheses on the individual cell behaviour against observed macroscopic properties. An example will be presented (individual behaviour: memory of cells, macroscopic property: chemotactic wave paradox).

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**MS71**

### Mechanisms for Biofilm Heterogeneity

Biofilms are colonies of bacteria enmeshed in a polymeric gel (EPS). EPS locks the bacteria in place and serves as a protective barrier to anti-microbials. Although EPS makes up the majority of biomass within the biofilm, it has been neglected in most models of biofilm growth. We present a model based on the physical and chemical structure of the EPS and describe analysis which indicate that structure of the EPS may be responsible for biofilm heterogeneity.

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**MS71**

### A Continuum Approach to Modeling Platelet Aggregation

A continuum model of platelet aggregation in large arteries is presented. The blood and aggregating platelets are treated as a single fluid with varying material properties to account for links between platelets. Analysis and simulation of the most general model is difficult because there are two distinct spatial scales, the scale of the fluid and the smaller scale of platelet interactions. Approximations for closing the system on the fluid scale are presented and

evaluated.

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### MS71

### Enzymatic Degradation of Insoluble Fibrillar Gels

Degradation of fibrillar gels is a key process in an increasing number of controlled release devices, as well as in physiological problems such as blood clot dissolution. I will present a reaction diffusion model for the enzymatic degradation of fibrillar collagen, and analyze it in the limit of fast diffusion. This analysis employs some recent results on the total quasi steady state approximation of the Michaelis Menten kinetic scheme.

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### MS71

### The Hydration Dynamics of Polyelectrolyte Gels With Applications to Cell Motility

By combining the physics of gels with the hydrodynamics of two-phase fluids, we construct a set of equations that describe the dynamics of polyelectrolyte gels. Solution of these equations is consistent with previous theory and experiments on gel swelling. We apply the model to the motility of nematode sperm cells and the swelling dynamics of polyelectrolyte gels used for drug release.

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### MS72

### Semi-strong pulse interactions

Pulse-pulse interactions play central roles in pattern formation phenomena, including self-replication. In this talk a geometric theory for the semi-strong interaction of pulses in a class of reaction-diffusion equations will be discussed (this class includes Gierer-Meinhardt, and Gray-Scott models). The theoretical insights will be illustrated by some explicit example problems of Gierer-Meinhardt type. These examples indicate that (localized) finite-time blow-up phenomena, as well as the self-replication process, appear naturally among semi-strongly interacting pulses.

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### MS72

### Spike Dynamics of a Reaction-Diffusion Equation and a Conjecture About the Modified Green's Function.

Many reaction-diffusion systems exibit spike-like formations, whereby the solution tends to concentrate at certain points of the domain. These spikes may move very slowly in time, oscillate up and down, or even split. All three of these basic phenomena occur in the Gierer-Meinhardt model for various parameter regimes. In this talk I will concentrate on a single spike movement. Spike movement and equilibria locations can be described asymptotically by an ODE that involves the regular part of the Green's function which depends on the diffusivity constant $D$ and the shape of the domain. We conjecture that for large enough $D$, the equilibria location for one spike is unique, even for a non-convex domain. We prove this conjecture for a certain family of dumbell-shaped domains using techniques from complex analysis. The general case, however, is still an open problem. This behaviour is very different than what happens when $D$ is small: in this case, we show that the stable equilibria are located at the points which are near the local maxima of the distance from the boundary.

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### MS72

### Transients, Mixed-Mode Oscillations, and Canards in a Coupled Oscillator Model of the Dopaminergic Neuron

We study a coupled oscillator model of the dopaminergic neuron. The salient features of the dynamics of the model include synchronous oscillations, slow transients, and mixed-mode oscillations. The analysis uses techniques of the geometric theory of singular perturbations, asymptotic expansions, and direct Lyapunov's method. The biological motivation for the analysis is understanding the mechanisms for different firing patterns of dopaminergic neurons. This is work in progress and is in collaboration with J.C. Callaway, N. Kopell, and C.J. Wilson.

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### MS72

### Stable two bump solutions of memory models

We investigate the existence and stability of families of one and two bump solutions when the coupling function has three zeros. In this case it is possible that parameters exist for which two stable one bump solutions and two stable two bump solutions coexist.

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**MS73**

### DNA Structural Transitions and their Roles in Mechanisms of Regulation

The stresses imposed on DNA are stringently regulated in vivo by a variety of processes. In particular, the untwisting torsional stresses produced by negative DNA superhelicity can destabilize the DNA duplex, causing its strands to separate at specific positions where the thermodynamic stability is low. We have developed computational methods to predict the destabilization properties of superhelical DNA molecules having any specified base sequence. The energy and conformational parameters used in this analysis are all taken from experimental measurements, so there are no free parameters in this model. Yet when it is used to analyze specific DNA sequences, the results of this method are in quantitatively precise agreement with experimental measurements of the locations and extents of local strand separations. This justifies its use to predict the duplex destabilization properties of other DNA base sequences, on which experiments have not been performed. A wide variety of genomic DNA sequences have been analyzed in this way. The sites of predicted duplex destabilization within these sequences do not occur at random, but instead are closely associated with specific types of DNA regulatory elements. Examples include promoters and transcription termination sites, origins of replication, and positions where the DNA is putatively attached to the chromosomal matrix. In collaboration with experimental groups we have found several regulatory systems whose mechanisms involve stress-induced DNA duplex destabilization. In this talk we will describe a variety of these applications.

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**MS73**

### Base-pair and Continuum Mechanics Models of DNA

Constitutive relations for rigid base-pair and continuum rod models of DNA are discussed. First, a method to extract a complete set of sequence-dependent energy parameters for rigid base-pair models of DNA from Molecular Dynamics (MD) simulations is described. The method is properly consistent with equilibrium statistical mechanics, and leads to effective inertia parameters for the base-pair units as well as stacking and stiffness parameters for the base-pair junctions. Second, matching relations for passing parameters between the base-pair and continuum rod models are presented. The relations provide an explicit correspondence between the parameters in a base-pair model with a non-standard choice of junction variables and those in a discretized rod model.

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**MS73**

### Conformational Mechanics of DNA Phase Transitions

The alphabet of DNA fiber structures, roughly 40 known double helical structures other than the classic A and B-DNA forms, is poorly understood at the level of sequence and environment. New information about the transition pathways which link the different conformational states is surfacing in the base-pair geometry and contact patterns in protein- and drug-DNA crystal complexes. This knowledge is helping us characterize the interplay of DNA structure and local surroundings and develop models of large nucleoprotein complexes in different chemical environments.

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**MS73**

### What Does the NDB Say About DNA Structure? A Statistical Survey of the NDB Database

We assess the bioinformatic utility of B-DNA structures solved by X-ray diffraction and NMR spectroscopy by examining how base-pair step geometry varies with local environment. A statistical survey of the Nucleic Acid Database (NDB) reveals that crystal structure-specific interactions exert non-negligible influences on base-pair step geometry. In addition, the comparison of solution NMR structures with crystal structures shows these two classes exhibit radically different patterns of sequence-dependent structural variation. We find that ancillary factors, such as crystal packing type and distance from the oligomer end, exert systematic and statistically significant effects on the experimentally measured DNA base pair geometric parameters. With current data it is difficult to disentangle these artifactual factors from actual sequence-dependent effects. It is not possible to make statistically valid inferences of sequence-dependent variations in most geometric parameters of B-DNA based solely on the structures presently in the NDB database. A larger sample of crystal and NMR structures could enable the resolution of many existing ambiguities.

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**MS74**

### Localization of Moving Low-frequency Sounds

Responses of mammals to moving sound sources have been studied at the level of responses of single cells and at the level of perception (psychophysics). In this talk we present a biophysically-based model that explains multiple features of single cell response, due to the presence of intrinsic cellular mechanisms of firing rate adaptation and post-inhibitory rebound. We also discuss how we can try to begin reconciling the single cell findings with psychophysical data.

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**MS74**

**Inhibitory Delayed Feedback Required for Differential Responses to Prey and Communication Stimuli**

Weakly electric fish use their electrosense to both locate prey and comminicate with conspecifics. We show that the primary sensory neurons of these animals oscillate in resposne to comminication signals but not to prey input. An ensemble of leaky integrate-and-fire neurons can reproduce this discrimination only when they are coupled via global delayed inhibitory feedback. This prediction is verified by experimental blockade of feedback pathways in these animals. Theorectical work shows that this effect is a noise induced transition through a Hopf bifurcation in the mean field dynamics.

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**MS74**

**Modeling Neural Mechanisms of Selectivity and Sequence Generation in the Songbird**

In songbirds, the brain structure HVc plays a key role in the generation and recognition of the syllable sequences that make up a song. Neurons in HVc respond selectively to both individual syllables and temporal combinations of syllables as they appear in the bird's own song. We present a computational model of HVc that produces syllable- and temporal-combination-selective responses on the basis of input from recorded bird songs filtered through spectral temporal receptive fields similar to those measured in lower auditory areas that project to HVc. Normalization of the input is shown to be critical for generating syllable-selective responses. For temporal-combination-selective responses, slow synaptic currents provide a memory that allows inhibitory neurons to gate responses to a final syllable in a sequence on the basis of responses to earlier syllables. When the same network that produces temporal-combination-selective responses is excited by a nonspecific timing signal, it generates a similar pattern of output as it does in response to auditory song input. Thus, the same model network can perform in both sensory and motor modes, as it does in the songbird.

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**MS74**

**Interactions Between Distinct Motor Behaviors Determined by Feedback to Modulatory Neurons**

Abstract not available at time of publication.

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**MS75**

**Chains of Bubbles in Polymers: Unusual Outcome of Rayleigh-Taylor Instability**

Motion of bubbles in a liquid is a ubiquitous yet very nontrivial phenomenon. The available body of knowledge and even its language connotation consider bubbles only as a discrete, detached from each other, units. It turns out that in concentrated polymer solutions bubbles may form a qualitatively new structures. The experiments shows that bubbles may form a very stable, continuous, slowly rising, connected long chains similar to beads, or bubble "sausage". Rayleigh-Taylor instability and strong elastic properties of polymer lead to such beautiful and unusual structures.

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**MS75**

**Unsteady Growth of Viscous Fingers**

Our experiments on viscous fingering in Hele-Shaw cells examine the unsteady growth of fingers in linear cells. Though viscous fingering has been studied for over forty years, our experiments have revealed unexpected finger width fluctuations and pinch-off events. These phenomena are robust but unexplainable by current theories. In addition, we have studied the statistics of the tip-splitting instabilities of viscous fingers and compared these with recent theories on the dynamics of finger growth.

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**MS75**

**Phase-change Phenomena and Connected Instabilities**

A solidification and electrodeposition instability will be compared to problems of evaporative instability. In the first problem surface tension affects the melt point, in the second it affects the electron transfer rate at the surfaces and in the third it plays the usual role of affecting the pressure differences while its effect on phase equilibrium is small. This talk will explain interesting physics that can be gleaned from picture arguments and simple models.

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**MS75**

**Faraday Wave Pattern Selection via Multifrequency Forcing**

Standing wave patterns may form on the surface of a fluid

subjected to a periodic vertical acceleration. We show how three wave interactions can be significantly enhanced by three-frequency forcing with frequencies in ratio $m : n : 2|m - n|$. We use bifurcation theory and spatio-temporal symmetry arguments to determine how the relative phases associated with the forcing function should be chosen to maximize three-wave interactions. We test our predictions by numerically computing coefficients in the bifurcation equations from the hydrodynamic model.

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### MS76
### SlideCont: An Auto97 driver for Sliding Bifurcation Analysis

SlideCont, an Auto97 driver for sliding bifurcation analysis of discontinuous piecewise-smooth autonomous systems, known as Filippov systems, is described in detail. Sliding bifurcations are those in which some sliding on the discontinuity boundary is critically involved. The software allows for detection and continuation of codimension-1 sliding bifurcations as well as detection of some codimension-2 singularities, with special attention to planar systems (n=2). Some bifurcations are considered also for n-dimensional systems.

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### MS76
### Applications of Nonsmooth Dynamical Systems to Chaotic Communications

In this talk we consider a practical application of nonsmooth dynamical systems to improve the performance of chaotic communication schemes. We show how the choice of chaotic dynamical system generating the transmitted signal is crucial. We further show how understanding the dynamics, using bifurcation theory of nonsmooth systems, permits optimisation of various measures of performance of the communication scheme, such as bit error rate, stochastic properties and bandwidth efficiency.

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### MS76
### Analysis of Codimension-2 Sliding Bifurcations in a Representative Example of a Dry-friction Oscillator

We are aiming at presenting a method of analysing codimension-2 sliding bifurcations, which can occur in Filippov type dynamical systems. A tool allowing such an analysis is based on an appriopriate composition of normal form mappings obtained for the codimension-1 sliding bifurcations. To present our analytical approach we will consider a dry-friction oscillator with external forcing, which in the non-dimensionalised form can be expressed as:

$$\ddot{x} + x = \sin(\omega t) - F\mathrm{sgn}(\dot{x}). \tag{2}$$

The system has been extensively studied, but never from the standpoint of bifurcation theory of PWS systems. Codimension-2 sliding bifurcations correspond to simultaneous occurrence of two codimension-1 sliding bifurcations. In particular, we will focus our attention on a grazing-sliding and a multisliding bifurcation of a periodic orbit occurring simultaneously. Therefore, a composition of the normal forms for grazing and multisliding bifurcations will be presented leading to the unfolding of the codimension-2 sliding bifurcation. Our approach can be used to analyse other possible cases of codimension-2 sliding bifurcations which, we believe, may widely occur in systems with discontinuous vector fields.

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### MS76
### Using Discontinuities for Stabilization of Recurrent Motions

The ability to calculate the stability characteristics of repetitive motions in the presence of discontinuities are used to derive a control method that include small, discrete changes of some state variables. Here, corrective adjustments to the ankle angles in a class of two-legged passive walkers are employed to affect the local stability of a periodic reference gait. It will be shown that a strongly unstable gait can successfully be stabilized and a collapse is avoided.

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### MS77
### Which is the Domain of Validity of the Standart Diffusive Term $-\mu\Delta u$?

We will give some mathematical results for different models occuring in fluid dynamics such as a phase transition model, a pollution spread model, a low Mach number combustion model and a shallow water model. More precisely, we will look at the dependence of the viscosity $\mu$ with regard to the density $\rho$ or the height of free surface $h$. We prove, for appropriate diffusive terms, the global existence of weak solutions without smallness assumption on the data. Similar results seem out of reach with the standart diffusive term $-\mu\Delta u$ obtained for $\mu \equiv$ Constant.

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**MS77**

**Large-scale Vortices and Small-scale Waves in Fluid Dynamics**

The co-existence and interactions between large-scale vortices and small-scale waves is typical for many fluid-dynamical problems, especially in geophysical fluid dynamics. A prominent example is given by small-scale inertia-gravity waves in the atmosphere, which can interact with global-scale circulations in a variety of ways and which thereby contribute to climate dynamics. These interactions are too small in spatial scale to be resolvable even on the most powerful supercomputers: capturing these effects is only possible using mathematical theory. This talk will describe some topical work on this problem, such as a recently discovered new interaction effect to do with wave scattering by vortices.

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**MS77**

**Global Well-posedness and Finite Dimensional Global Attractors for 3-D Planetary Geostrophic Models**

We consider two 3-D planetary geostrophic models of the gyre-scale midlatitude ocean: one is viscous model and the other is with hyper-viscosity. For these models, we show the global existence and uniqueness of the weak and strong solutions. Moreover, we establish the existence of finite dimensional global attractor to these dissipative evolution systems.

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**MS77**

**On Improved Bounds for Finite and Infinite Prandtl Number Rotating Convection**

Using the background profile method, it is possible to obtain upper bounds on the energy dissipation for rotating Rayleigh-Benard convection that scale with the Rayleigh number and the Ekman number. In the case of infinite Prandtl number, these bounds show that high rotation rates completely suppress convection. New results show that the Nusselt number is bounded by $CE^{1/3}R^{2/3}$ which improves upon previous bounds for very high rotation rates. In the case of large (but finite) Prandtl number system, it is possible using similar techniques to obtain a bound of $CR^{2/5}$, on a finite time interval. This bound is uniform in rotation rate.

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**MS78**

**Some Topological Obstructions in 2D Inviscid Fluid Flows**

Since inviscid 2D fluid flows passively transports their vorticity, the time $T$-flow map, $f$, of a $T$-periodic invisicid flow preserves the level sets of its initial vorticity. Thus if the initial vorticty has nonvanishing gradient almost everywhere, $f$ is not chaotic. This is a well known. However, certain topologocial configurations of "stirrer" motions always imply chaos by the Thurston-Nielesen theory, and so can only happen for irrotational, invsiscid periodic flows. We explore ramifications and generalizations.

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**MS78**

**Elliptic Boundary Value Problems from a Symplectic Point of View**

The Morse index for the minimizer of an elliptic boundary value problem is given a symplectic interpretation as the Maslov index for two classes of Lagrangian subspaces in some symplectic Hilbert space. These Lagrangian subspaces are naturally associated with the boundary conditions and the solution of the elliptic PDE. Infinite dimensional Lagrangian-Grassmanian theory is developed here to get the results above.

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**MS78**

**Singular Boundary Value Problems Via the Conley Index**

We use Conley index theory to solve singular boundary value problem $\epsilon^2 u'' + f(u, x) = 0$ on interval $[-1, 1]$. Since we use topological methods the assumptions we need are weaker then the standard set of assumptions. The Conley index is used to track certain cohomological information which guarantees existence of a solution to BVP.

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**MS78**

**Geometry of Basic Sets of Smale Flows**

This will likely be something different, as it will be half a year into the future. The aim is to understand how one-dimensional basic sets can be embedded in flows on 3-manifolds. The primary model for one-dimensional basic sets is provided by templates (branched 2-manifolds with expansive flow), obtained by collapsing a Markov flowbox neighborhood of the basic set along its stable foliation. We describe an algorithm telling whether a given template can be part of some non-singular Smale flow on the 3-sphere.

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**MS79**

**Slow Manifold for Bimolecular Association Mechanism**

Two-variable ODE models of chemical reactions often have slow manifold corresponding to the global slow relaxation of the system. To find the slow-manifold a functional equation is iterated; another method is series solution of an ODE. These two methods may agree. However, a counterexample is discussed where iteration works but series expansion fails, e.g. A + B ¡=¿ C -¿ P . The behavior of this reaction is investigated and compared with other two-step mechanisms.

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**MS79**

**Fundamentals of the Computational Singular Perturbation Method**

In systems of stiff Ordinary Differential Equations, both fast and slow time scales are encountered. The fastest time scales are responsible for the development of low dimensional manifolds on which the trajectory moves according to the slower time scales. The CSP method is an iterative procedure which identifies both the manifold and the nonstiff system which governs the trajectory's motion on the manifold. In this talk, the theoretical foundation of CSP will be presented.

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**MS79**

**Intrinsic Low-Dimensional Manifolds - Recent Progress and Remaining**

The concept of intrinsic low-dimensional manifolds (ILDMs) has been proven to be an efficient tool for the simplification of chemical kinetics. Recent progress and remaining challenges related to this concept will be discussed.In particular we shall focus on three different aspects, namely hierarchical concepts for an efficient generation of ILDMs, an efficient implementation in laminar and turbulent flow calculations, and the extension to multiphase systems.

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**MS79**

**Low-Dimensional Manifolds in Reaction-Diffusion Systems**

This work addresses the construction of low dimensional manifolds for chemically reacting flows. This construction relies on the same decomposition of a local eigensystem that is used in formation of what are known as Intrinsic Low Dimensional Manifolds (ILDMs). We first clarify the accuracy of the standard ILDM approximation to the set of ordinary differential equations which model spatially homogeneous reactive systems. It is shown that the ILDM is actually only an approximation of the more fundamental Slow Invariant Manifold (SIM) for the same system. Subsequently, we give an improved extension of the standard ILDM method to systems where reaction couples with convection and diffusion. Reduced model equations are obtained by equilibrating the fast dynamics of a closely coupled reaction/convection/diffusion system and resolving only the slow dynamics of the same system in order to reduce computational costs, while maintaining a desired level of accuracy. The improvement is realized through formulation of an elliptic system of partial differential equations which describe the infinite-dimensional Approximate Slow Invariant Manifold (ASIM) for the reactive flow system. This is demonstrated on a simple reaction-diffusion system, where we show that the error incurred when using the ASIM is less than that incurred by use of the Maas-Pope Projection (MPP) of the diffusion effects onto the ILDM.

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**MS79**

**Analysis of the CSP Reduction Method for Chemical Kinetics**

We examine the asymptotic accuracy of the Computational Singular Perturbation (CSP) reduction method, developed by Lam and Goussis to reduce the dimensionality of a system of chemical kinetics equations. We show that successive refinement steps of the method generate, order by order, the asymptotic expansion of a slow manifold. The said analysis also links the ILDM method of Maas and Pope to CSP. This link can be exploited to improve the accuracy of the former.

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**MS80**

**Boundary Effects on Chaotic Advection-Diffusion Chemical Reactions**

Theory of fast binary chemical reaction, $\mathcal{A}+\mathcal{B}\to\mathcal{C}$, in a statistically stationary bounded chaotic flow at large Peclet

number Pe and large Damköhler number Da is described. For stoichiometric condition we identify subsequent stages of the chemical reaction. The first stage correspondent to formation of the developed lamellar structure in the bulk part of the flow is terminated by an exponential decay, $\propto \exp(-\lambda t)$ (where $\lambda$ is the Lyapunov exponent of the flow), of the chemicals in the bulk. The second and the third stages are due to the chemicals remaining in the boundary region. During the second stage the amounts of $\mathcal{A}$ and $\mathcal{B}$ decay $\propto 1/\sqrt{t}$, whereas the decay law during the third stage is exponential, $\propto \exp(-\gamma t)$, where $\gamma \sim \lambda/\sqrt{Pe}$. Some brief discussion will also be given to effect of the chemicals (aerosols) inertia on the reaction dynamics. This is a joint work with V. Lebedev (Landau Institute).

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**MS80**

### Inertial Particles in Slurry Flows

Particles suspended in a fluid medium often do not follow the trajectory of the fluid phase. Hence, predicting locations of fine particles in multiphase flows becomes very computationally intensive. To model slurry flows in which the overall suspension is a depth-average continuous medium, we choose the simplest conditions for the particles. Specifically, we assume that the particles settle while advecting along the fluid trajectory. This method allows us to track the locations of the particles in the suspension medium separately from the overall flow. This work is motivated by the experimental observation that fine particles suspended in a horizontally rotating cylinder exhibit a complicated phase separation and a multiply periodic axial stability. The model shows agreement with experimental observations and gives concrete predictions for the spatial evolution of phase separation in slurry dynamics.

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**MS80**

### Activity of Inertial Particles in Nonhyperbolic Open Flows

We investigate the anomalous kinetics of infective (e.g., autocatalytic) reactions in open chaotic flows when the massless advection dynamics is nonhyperbolic. We show that the singular enhancement of the production due to fractal patterns is determined by an effective fractal dimension and an effective escape rate, which are in general significantly different from the respective fractal dimension and escape rate of the underlying advection dynamics. This is in sharp contrast with previous results for flows where the massless advection dynamics is hyperbolic. Strikingly, the effective quantities are also relevant for inertial particles, even though the advection dynamics of these particles is hyperbolic.

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**MS80**

### The Dynamics of Finite Size Neutrally Buoyant Particles

The forces acting on a small rigid neutrally buoyant spherical tracer particle in an incompressible two-dimensional fluid flow is reviewed. By means of a simplyfied model of these forces it is shown that tracer trajectories may separate from fluid trajectories in those regions where the flow has hyperbolic stagnation points. A tracer will evolve only on fluid trajectories with Lyapunov exponents bounded by the value of its reciprocal Stokes number. By making the Stokes number large enough, one can force a tracer in a flow with chaotic path lines to settle on either the regular KAM-tori dominated regions or to selectively visit the chaotic regions with small Lyapunov exponents.

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**MS80**

### Inertial Advection in Open Flows

The inertia a tracer trajectories has essential effect on their trapping properties in the wake of bluff bodies. Particles havier than the fluid have a shorter lifetime, while light particles stay in wake for longer periods, on average. Their escape rate can become drastically smaller. Parameter regimes are found where even a permanent trapping is possible due to the appearance of periodic or chaotic attractors in the wake. We point out that fractal basins of attractions exist, and that the sensitive dependence on the parameters can be used for segregating such particles via a 'chaotic chromatograph'.

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**MS80**

### Inertial Advection in Three-dimensional Flows

The bailout embeddings of 3D volume-preserving maps are used to study qualitatively the dynamics of of finite-size spherical neutrally-bouyant impurities suspended in a time periodic incompressible fluid flow. Accumulation of impurities in tubular vortical structures, detatchment of particles from fluid trajectories near hyperbolic invariant lines and the formation of nontrivial 3D structures in the distri-

bution of particles are predicted.

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### MS81
### Heteroclinic networks as templates for complex dynamics

We describe recent work in the thesis of Manuela Aguiar (Porto) on some of the remarkably robust and complex dynamics associated to a "Shilnikov network" which occurs in a symmetric 3-dimensional system of ODEs, first described by the author. Switching between nodes of the network is quantified by a subshift of finite type.

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### MS81
### A mechanism for switching in a heteroclinic network

The dynamics near a network of heteroclinic cycles can potentially be extremely complicated. For instance, two or more cycles in a network may simultaneously attract significants sets of trajectories. However, most studies to date have found that a trajectory that stays near a heteroclinic network is eventually attracted to one of the cycles in the network. This talk describes a deterministic mechanism which induces repeated, possibly chaotic, switching of trajectories between different cycles in a network.

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### MS81
### The 1:2 Spatial Resonance in Rayleigh-Bénard Convection

In the absence of midplane reflection symmetry wavelength selection in the two-dimensional Rayleigh-Bénard problem is dominated by the 1:2 spatial resonance. With periodic boundary conditions the unfolding of this mode interaction problem contains a rich variety of time-dependent solutions, including traveling and standing waves, modulated traveling waves and structurally stable heteroclinic cycles. In this talk recent results on this problem will be described and compared with the results of direct numerical simulations of low Prandtl number convection.

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### MS81
### Global bifurcations and heteroclinic cycles in the nonlocal parametrically driven NLS equation

Faraday waves are described, under appropriate conditions, by a damped nonlocal parametrically driven NLS equation. With increasing forcing this equation undergoes a sequence of transitions to chaotic dynamics organized by heteroclinic connections between the trivial state and spatially periodic standing waves. These connections can be understood within a low-dimensional model and originate in a (codimension-two) heteroclinic bifurcation joining three distinct equilibria; the unfolding of this bifurcation reveals nested cascades of additional heteroclinic and homoclinic bifurcations.

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### MS81
### Loss of stability of cycling chaos

Structurally stable heteroclinic cycles between equilibria in symmetric systems are well documented phenomena. Similar cycling is also possible between more complicated sets, such as chaotic saddles. We investigate the bifurcation at which such 'cycling chaos' gains/loses stability, and find two different outcomes when cycling chaos is destroyed: either a plethora of stable high-period periodic orbits, or chaotic dynamics intermittent to invariant subspaces. Which one is seen depends on the dimension of the connections between invariant subspaces.

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### MS81
### Heteroclinic cycles and Kelvin-Helmholtz instability in the flow between exactly counter-rotating disks

The competition between instabilities with wavenumbers 1 and 2 is described by a normal form which displays a rich variety of dynamical states, including steady states, traveling waves, modulated traveling waves and heteroclinic cycles which persist over a range of parameter values. Three-dimensional nonlinear computations of the flow between exactly counter-rotating disks separated by a distance equal to the diameter show the same behavior,

demonstrating that this von Karman flow is a fluid dynamical realization of the 1:2 mode interaction. Open questions raised by our simulations concern the saturation of the period and of the distance from the heteroclinic cycle, and the existence of two distinct types of quasi-heteroclinic orbits, which can consist of either two or four plateaus. We also propose a physical interpretation of the instability as resulting from a generalization of the Kelvin-Helmholtz mechanism.

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### MS82

### On Time-asymptotics of the Domain of Spatial Analyticityfor Solutions of the Generalized KdV-equation

Starting from analytic initial data and assuming certain a priori Sobolev-type boundness, *algebraic* lower bounds on the rate of decrease in time of the uniform radius of spatial analyticity of solutions of the GKdV-equation are derived. In order to efficiently exploit dispersive effects in analytic classes, analysis in Bourgain-type analytic Gevrey spaces is developed. This is joint work with J.L. Bona and H. Kalisc

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### MS82

### Asymptotic Analysis of the Primitive Equations in Thin Domains

In this talk I will first recall some existence results concerning the strong solution of the Primitive Equations for atmosphere and ocean under small depth assumption, then we will investigate the asymptotic behavior of the solutions of PEs as the depth goes to zero.

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### MS82

### Numerically Determining Modes for the Lagrangian Averaged Navier-Stokes Alpha Model

We employ a computational technique used in weather forecasting called continuous data assimilation to numerically study the number of determining modes and degrees of freedom in the two-dimensional Lagrangian averaged Navier-Stokes Alpha Model of turbulence. Our focus is on how the number of determining modes depends on the averaging length scale Alpha.

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### MS82

### On the Backwards Behavior for the 2D Periodic Kelvin Filtered Navier-Stokes Equations

For a class of two-dimensional periodic Kelvin filtered Navier-Stokes systems, sets which consist of initial data for which the solutions exist for all negative times and whose Dirichlet quotients (enstrophy/energy) demonstrate a certain asymptotic behavior backwards in time are investigated. For a class of filters we prove that the set of the initial data for which solutions exist for all negative times is dense in the phase space with respect to the energy norm of the system. This result is the equivalent of the Bardos-Tartar conjecture (1973) for the Navier-Stokes Equations.

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### MS82

### The Two-dimensional Quasi-geostrophic Equation

The 2D quasi-geostrophic (QG) equation is a two dimensional model of the 3D incompressible hydrodynamic equations. It has been proposed and studied to develop mathematical insight in the open problem of whether smooth solutions of the 3D fluid equations become singular in a finite time. In addition, the 2D QG equation is also relevant in the context of general quasi-geostrophic models of atmospheric and ocean fluid flow. The issue of global existence for the 2D QG equation is non-trivial. I will review results for the 2D dissipative QG equation with an index ranging from subcritical to supercritical.

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### MS83

### Adaptive Sampling Strategies for Fleets of Autonomous Underwater Gliders

In this talk we present sampling strategies for fleets of coordinated underwater gliders (fixed-wing, buoyancy-driven autonomous underwater vehicles) serving as adaptive ocean sensors. We develop these strategies making use of our multiple coordinated vehicles framework in which group translation, rotation and expansion are effected in response to measured data. These strategies enable cooperating gliders to effectively perform tasks such as gradient climbing or sampling in and around a front or feature of interest.

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### MS83

### Planar propulsion through the manipulation of circulatory flows

The development of thrust forces on the control surfaces of an important class of swimming vehicles corresponds to the manipulation of circulatory flows about these surfaces. We examine circulation-based propulsion as it pertains to two archetypical systems, one theoretical and one experimental. First we present and analyze a planar model for carangiform locomotion in which the strength and relative position of a trailing point vortex are controlled to propel

a rigid body; the flow around the vortex in this case approximates the flow around an oscillating hydrofoil. Then we present motion-planning results for the underactuated nonlinear control system consisting of an aquatic Flettner rotor with full planar mobility.

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**MS83**

**Locomotion with flexing and oscillating foils**

I will discuss planar "fishlike" swimming, using an oscillating tailfin which may be a flat plate or a Joukowski foil, and may be rigid or actively flexible. The dominant forces behind propulsion may be virtual-mass forces or lift forces, depending in part on the characteristic frequency of the swimming. I will present computer simulations and in some cases experimental data.

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**MS83**

**Oscillatory Shape Actuation for Underwater Locomotion**

Underwater locomotion and propulsion for underwater vehicles provide rich applications for the development of control methods for nonlinear systems and underactuated mechanical systems. In this presentation, the tasks of gait generation and of trajectory tracking for robots built with a fish-tail type propulsive device are considered. Using a combination of open loop oscillatory control for gait generation and discrete time state feedback for error correction, the task of planar trajectory tracking can be accomplished. Simulations and experiments demonstrate the results.

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**MS83**

**Symmetry, Reduction and Swimming in a Perfect Fluid**

We discuss the configuration space of a deformable body in a perfect fluid and show how this system fits into the general framework of simple mechanical control systems with symmetry. We review how this system can be reduced to a finite dimensional system when we consider the shape of the body to be under our control. As an example we consider the mobility of three connected rigid bodies in a plane filled with a perfect fluid where for simplicity we assume the bodies are mechanically but not hydrodynamically coupled. We discuss the controllability of the system and demonstrate some of its gaits.

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**MS83**

**Dynamically Interacting Solid Body-Vorticity Field Systems**

A solid body (rigid or deformable) interacting dynamically with the vorticity field of an incompressible fluid external to it maybe viewed, at an inviscid level, as the vortical extension to the classical Kirchhoff system. Methods of deriving the equations of motion of such systems, using variational and momentum balance principles, will be discussed. In particular, the Hamiltonian structure of a simple system of a 2-D rigid cylinder and N point vortices will be examined.

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**MS84**

**Coupled FitzHugh-Nagumo Equations**

We examine traveling waves for spatially continuous and for spatially discrete FitzhHugh-Nagumo equations. Of particular interest are coupled systems where the couplings model phenomena such as ephaptic coupling between parallel nerve fibers and ohmetric coupling in cardiac tissue.

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**MS84**

**Computing Travelling Wave Solutions in a Neuronal Network**

We consider a neuronal network model with axo-dendritic synaptic interactions of Coombes, Lord and Owen which admits travelling wave solutions defined by functional differential boundary value problems with both advanced and retarded terms. We describe a general purpose code for solving such problems and show how it can be applied to compute travelling wave solutions for this neuronal network and for general lattice differential equation travelling wave problems.

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**MS84**

**Traveling Waves for a Generalized FitzHugh-Nagumo Equation**

Consider the following generalized FitzHugh-Nagumo equations

$$u_t = u_{xx} + f(u,w), \quad w_t = \epsilon g(u,w)$$

where $f(u,w) = u(u - a(w))(1-u)$ for some smooth function $a(w)$ and $g(u,w) = u - rw$. By allowing $a(w)$ to cross zero and one, the corresponding traveling wave equation possesses special turning points which result in a very rich dynamic. In this work, we will examine the existence of fronts, backs and pulses solutions; in particular, the coexistence of different fronts will be discussed.

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## MS84

### A Construction Technique for Heteroclinic Solutions to Continuous and Differential-Difference Damped Wave Equations

We give a systematic construction procedure for finding explicit heteroclinic travelling wave solutions to continuous and differential-difference damped wave equations. These equations arise in various fields such as neurophysiology, materials science, and solid state physics. In some limiting cases, we recover the well-known solutions of the Nagumo and sine-Gordon equations. We also find explicit solutions with multiple steps corresponding to multistable nonlinearities.

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## MS84

### Computation of Modulated Waves in Reaction-diffusion Systems

Among the waves that have been observed in numerical simulations of reaction-diffusion systems are modulated waves which are solutions that are time-periodic in an appropriate co-moving coordinate frame. I discuss the computation of modulated waves using a boundary-value problem approach. This allows us to use AUTO2000 for the computation of modulated waves even if the waves are unstable with respect to the PDE.

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## MS84

### Traveling Waves in Discrete FitzHugh-Nagumo Equations

We consider a spatially discrete FitzHugh-Nagumo equation to model ionic conductances that generate the action potential of nerve fibers in motor nerves of vertebrates. We show existence both analytically and numerically of front and pulse solutions and discuss extensions to coupled systems of spatially discrete FitzHugh-Nagumo equations.

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## MS85

### A Coarse Computational Approach to Lattice Dynamics

We explore a computer-assisted approach to homogenizing the dynamic behavior of lattice dynamical systems (e.g. chains of coupled oscillators) that is based on the so-called coarse timestepper. In particular, we approximate numerically the timestepper of the (unavailable) translationally invariant effective equation, and study its dynamics and instabilities. We focus on the algorithm's approximation of the pinning of coherent structures as the discreteness parameter increases.

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## MS85

### Dendritic Effects in Networks of Spiking Neurons Connected by Inhibition and Electrical Coupling.

Fast-spiking interneurons in the cortex are connected by both inhibitory synapses and direct electrical coupling. We have recently studied model neurons connected by inhibition and electrical coupling and described how phase-locked states depend on coupling parameters and intrinsic cellular properties. Here we extend these results, examining how the location of coupling (i.e. dendritic or somatic coupling) can affect the phase-locking structure. We show that altering location can change the stability of phase-locked states.

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## MS85

### Simulation of Growth Cone Pathfinding through Complex Environments

During development and regeneration the neuronal growth cone is responsible for guiding its axon to its final target. We have developed a quantitative model for growth cone guidance in complex, biologically relevant environments. By manipulating the strength, attractive or repulsive nature, and arrangement of simulated guidance cues we can quickly infer how manipulating the growth cone's environment affects the growth cones ability to pathfind.

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## MS85

### Topology and Spinal Cord Repair

Numerous independent vertebrate motor and sensory systems decussate, or cross the midline to the opposite side of the body. The successful crossing of many thousands to millions of axons during development requires a complex of tightly controlled regulatory processes, so presumably decussation confers a significant evolutionary advantage. Yet the nature of this advantage is not under-

stood. In this paper, we examine constraints imposed by topology on the ways that a three dimensional processor and environment can be wired together in a continuous, somatotopic, way. We find that as the number of wiring connections grows, contralateral decussating arrangements become overwhelmingly more robust against occasional wiring errors than seemingly simpler ipsilateral wiring schemes. These results are mathematically general, yet they provide specific and concrete direction for improved understanding of clinical disorders (for example those in which decussation is hindered during development) and regeneration strategies (for example those involving sprouting across the midline).

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### MS85

### Modeling Dendritic Morphological Complexity Using Principles of Neural Development

Neurons grow out through dynamic actions of growth cones. Showing diverse behavior including elongation, branching, retraction, dormancy and disappearance, the ultimate outcomes are branching patterns with complex shapes. Many mechanisms are involved in the actual behavior of growth cones such that a description as a stochastic process of elongation and branching is assumed to be justified. We will show how these assumptions lead to characteristic shape properties of dendritic branching patterns for different cell types. Beyond the phenomenological level we will show examples of modeling underlying mechanisms including cytoskeletal dynamics.

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### MS86

### Simulation of Benard-Marangoni Convection in a Vertical Magnetic Field

Bnard-Marangoni convection in liquid metals is affected by the presence of a vertical magnetic field because the fluid is electrically conducting. To date, the effects of the magnetic field have been examined by means of linear stability theory and weakly nonlinear analyses. We study the nonlinear behavior numerically in the framework of the one-layer model with insulating boundaries using a three-dimensional spectal code based on a Fourier-Chebyshev expansion. The vertical flow structure is of particular interest.

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### MS86

### Surface-tension-driven Convection in Small Vessels

The goal of this study is to better understand the influence of the confinement onto the Bnard convection (threshold, bifurcation, stable or dynamical patterns). Experiments and numerical simulations have been performed in several shape and size containers, from the threshold up to roughly 1.6 Mac. Among some appealing results, the physical explanation of hexagonal cellular convection, the existence of intrinsic characteristics, some dynamical regimes close to the threshold (provided specific configurations are fulfilled) can be mentioned.

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### MS86

### Nonlinear Dynamics of Interfacial Convection in Benard Layers

Benard convection in layers presenting a free surface is most often studied assuming a Newton's cooling law at the free surface, with a heat transfer coefficient whose dimensionless form is the Biot number. In this presentation, we re-examine the validity of this assumption in several cases, including the possibility of evaporation. In this case, the Biot number can be much larger than for a non-volatile liquid, with strong consequences on nonlinear regimes and pattern selection.

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### MS86

### Non-potential Effects in Marangoni Convection in Thin Liquid Films

Non-potential effects in Marangoni convection in thin liquid films are investigated. Three manifestations of non-potential effects are considered: (i) spatial modulations of hexagonal patterns; (ii) interaction between a short-scale hexagonal pattern and a long-scale slow deformational (Goldstone) mode; (iii) generation of the mean flow by the free-surface deformation in a large-scale Marangoni convection with poorly conducting boundaries. Non-potential effects are shown to cause skewed hexagonal structures, co-existing up- and down-hexagons, oscillating hexagons, irregular cellular patterns, etc.

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### MS86

### Stability of Thermocapillary Flows

We consider typical kinds of instabilities characteristic for the thermocapillary flows, which generate various dynamic regimes. A special attention is paid to flows in a plane layer. In the case of an inclined temperature gradient, we investigate the interaction between two instability mechanisms that lead either to the formation of anistropic three-dimensional convective cells or to the excitation of hydrothermal waves. For sufficiently large values of the Bond number, the influence of the rigid lateral boundaries can produce a stationary multicellular flow which competes with the hydrothermal waves. This flow is subject to a specific kind of oscillatory instability.

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### MS86

### Penta-hepta Defect Chaos in Hexagon Patterns with Rotation

Surface-tension driven convection typically leads to hexagonal patterns. In contrast to spatio-temporal chaos based on stripe patterns, few studies are available for hexagon-based spatio-temporal chaos. We study a state of spatio-temporal chaos in weakly nonlinear hexagon patterns in rotating systems that is characterized by the dynamics of penta-hepta defects and sustained by the induced nucleation of dislocations. The induced nucleation drastically modifies the defect statistics compared to the usually observed Poisson distribution.

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### MS87

### Statistical Mechanics Models in Finite-temperature Micromagnetics

In this talk we discuss recent joint work with Petr Plechac (University of Warwick) on the derivation of an equilibrium statistical theory for the macroscopic description of a ferromagnetic material at finite temperatures. Our formulation is based on a suitably derived large deviation principle and describes the most-probable equilibrium macrostates that yield a coherent deterministic large-scale picture, varying at the size of the domain; furthermore it captures the effect of random spin fluctuations caused by the thermal noise. We discuss connections of the proposed formulation to the (zero-temperature) Landau-Lifschitz theory and to studies of domain formation based on Monte Carlo (MC) lattice simulations. Finally, in the nonequilibrium case we derive using interacting particle systems methods, a kinetic-type model for the time-dependent PDF of the magnetization. Some of the main difficulties in these probelms involve at the analysis side dealing with the long range dipolar interactions described by a singular integral operator. From a numerical perspective, and in addition to the usual limitations of MC algorithms, this singular term is sensitive to discretizations resulting to shifts in the predicted critical temperature.

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### MS87

### Dynamic Scaling Laws in Miscible Viscous Fingering

The interface between a heavy fluid resting above a light fluid in a porous medium is unstable to small perturbations. While a great deal of attention has been devoted to the stability of special solutions in these flows (for example, the Saffman-Taylor finger) relatively little is known theoretically about the long time evolution. The conventional wisdom is that instability of the free surface implies unpredictability of bulk behavior. This is in strange contrast to robust experimental and numerical evidence of simple dynamical scaling laws in these flows. In this talk, I will describe how one may rigorously understand some aspects of how the evolution of microstructure – a labyrinthine network of "fingers" – interacts with bulk transport. The tools are simple ideas from the theory of conservation laws, calculus of variations and stability of nonlinear waves. This is work with Felix Otto (Univ. Bonn).

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### MS87

### Particle Distributions and Fluctuations in Sedimentation

The spatial distribution of solid particles sedimenting under gravity at low Reynolds number conditions directly affects the velocity fluctuations of these particles. We have recently confirmed that, while independently positioned spheres (up to exclusion) do settle with velocity fluctuations that scale with the size of the container, the presence of a small stable background stratification in the particle density leads to statistically steady fluctuations independent of system size. This effect must then also be accounted for in model continuum equations for the particle concentration. We will also address the possibilities of generalizing these results to more complicated flows, including non-zero Reynolds number effects, orientational effects for ellipsoidal particles, and the Boycott effect. This presentation includes joint work with M. P. Brenner, and has been supported by the NSF.

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### MS87

### Discussion

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**MS87**

**Bridging Length and Time Scales in Materials Modeling**

Multiscale modeling is emerging as the new paradigm in scientific computation. Molecular simulations such as molecular dynamics and Monte Carlo algorithms have been established in the past few decades as one of the preeminent computational tools for science and engineering research. With the advent of enhanced computing capabilities, these methods can provide unprecedented insights into numerous problems ranging from physicochemical and biological processes, to biomaterials and drug design. Despite their widespread use and the substantial progress in related computational methods, molecular simulations are limited to short length and time scales. Furthermore, parametrization molecular models based on quantum scale information is necessary and their extension to the macroscopic scale is essential in order to fabricate and control various devices. A major obstacle in meeting this multiscale modeling challenge is the lack of a rigorous mathematical and computational framework providing a direct link of atomistic simulations and scales, to complex mesoscopic and macroscopic phenomena dictated by microscopic intermolecular forces. In this talk, a new mathematical framework will be introduced for multiscale modeling of materials. The specific problem focuses on nucleation and growth of zeolite nanoparticles and their use in fabricating membranes for separations, reactions, and as hosts for growth of optico-electronic materials. Multiscale challenges in linking microstructure with synthesis and membrane device properties will be addressed with an example of a MFI type zeolite. In particular, we will discuss (1) mesoscopic theory, (2) homogenization theory of mesoscopic equations, and (3) coarse-grained kinetic Monte Carlo simulations as tools of a multiscale simulation toolkit which enable us to bridge scales in a mathematically rigorous and systematic way.

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**MS87**

**Modeling Flows of Nematic Liquid Crystalline Polymers Using Kinetic Theories**

I will present a general Doi-type kinetic theory for nematic liquid crystalline polymers (LCPs) accounting for the molecular aspect ratio, excluded volume interaction, long-range intermolecular interaction, and chirality of the molecules. I will derive an approximate intermolecular potential for LCP molecules of the spheroidal shape and the elastic as well as the visocus stress expression corresponding to the shaped molecule being transported in viscous solvent. I will then show the theory obeys the second law of thermodynamics and "reduces" to the well-known Ericksen-Leslie theory for nematic liquid crystals in the weak flow, weak elasticity, and slow time limit. Applications of the theory and its moment approximations in simple flows will be discussed in the end.

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**MS88**

**On the Notion of Temperature in FPU Systems**

A numerical investigation is made for FPU systems in the regime in which the relaxation time to equipartition is extremely small. The interaction with heat baths is numerically investigated, and it is shown that the temperature is not equal to the mean specific kinetic energy.

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**MS88**

**On the Times of Relaxation to Equilibrium in FPU-Like Systems**

It is illustrated how, for low enough specific energy, the relaxation to equilibrium in the FPU system occurs in two time-scales. An analogy is also pointed out with the situation occurring for polyatomic molecules, where the presence of Levy jumps for the energy turns out to play a relevant role.

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**MS88**

**Stability of Solitary Waves on FPU Lattices**

The FPU lattice is a prototypical extended Hamiltonian system. We consider lattices with convex pair potential, and develop a geometric theory for solitary wave stability relating linear to nonlinear asymptotic stability. A key necessary condition is energy/wave-speed transversality. For waves with near-sonic speed, we verify the stability criterion by formulating it in a way that is robust in the KdV limit. This work is joint with Gero Friesecke at the University of Warwick.

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**MS88**

**Birkhoff's Normal Form for the FPU Lattice**

In their famous 1955 computer experiment, Fermi, Pasta and Ulam (FPU) discovered that a many particle Hamiltonian lattice can display quasi-periodicity and thus fail to thermalise. Nishida, in 1971, was the first to attempt and prove this by computing a Birkhoff normal form for the FPU lattice with fixed endpoints in order to apply the Kolmogorov-Arnol'd-Moser (KAM) theorem. Being unable to determine some important resonance relations, he could only make conjectures though. In this talk I will show that symmetries are crucial in determining these resonance relations. The equations of motion of the normal form are computed and analysed. Again using a symmetry argument, we find that Nishida's conjecture was correct and can be extended. Moreover, in the lattice with periodic boundary conditions, we find interesting bifurcations describing for instance how traveling waves can change direction.

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**MS88**

### Coherent Localized Structure Generation by Instabilities of the Invariant Manifolds of the FPU energy surface

Choosing a convenient Fourier representation of the FPU chain it is possible to proove that invariant submanifolds for the motion exist on the energy hypersurface. The lowest dimensional manifolds may correspond to periodic exact solutions (nonlinear waves). When these waves become unstable, a complex dynamical process begin which leads to the formation of coherent localized structures (CLS) bearing much resemblance to exact breathers. These CLS are able to collect very efficiently the energy on the chain and, therefore, their size grows in time. However, their fate is to finally die into the thermal disordered state of energy equipartition. Several stages of this complex process can be described by convenient approximate continuum representations (PDE) of the chain, but several others remain to be understood.

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**MS88**

### Resonances, Time-scales and Normal Forms for Chains of Oscillators

The solutions of coupled ode's like the FPU-chain can be approximated by normal form methods. The result is very sensitive to the resonances in the chain (if the chain arises from discretization of a pde the resonances occur in the spectrum of an associated linear operator). In their turn the resonances determine the time-scales on which nonlinear interactions are effective. We illustrate the theory by some examples among which a case where we have 'stability' on a long time-scale but instability on a longer one; also we will discuss the FPU-chain where a large number of resonances arise. As Bob Rink will show, symmetry considerations will solve this. The degenerate or non-degenerate character of a normal form is very important. For conservative systems this determines the applicability of the KAM-theorem if the normal form is integrable. From the (non-)integrability of the normal form we obtain an estimate for the measure of chaos.

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**MS89**

### Unsteady Separation in Three-Dimensional Flows

Unsteady flow separation has been a much-studied but unsolved problem ever since the publications of Prandl's classic results on steady separation in 1904. Van Dommelen, Shariff, Pulliam, and Ottino, however, showed that unsteady separation near a no-slip boundary is best described in the Lagrangian frame. It has also been accepted that unsteady separation is caused by non-hyperbolic unstable manifolds branching off the boundary. In this talk we review an exact kinematic theory that renders the location and shape of separation manifolds for two-dimensional flows. We then discuss the geometry of three-dimensional unsteady separation, and show initial results on a 3D extension of our theory.

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**MS89**

### Weak Finite-time Melnikov Theory and Viscous Perturbations of 3D Euler Flow

The equations for fluid particle trajectories are examined using a 3-D Melnikov approach. The theory assesses the destruction of 2-D heteroclinic manifolds (such as that present in Hill's spherical vortex) under a perturbation which is not differentiable in the small parameter nor defined for all time. The rationale for this theory is to analyze viscous flows that are close to steady Euler flows. An expression characterizing the splitting of the two-dimensional separating manifold is derived.

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**MS89**

### Multiscale Norm for Mixing and Application to Three-Dimensional Flows in Micromixers

In spite of a large amount of recent research on the problem of fluid mixing, there is no consensus on a proper measure for quantifying mixing. Here, we present a measure of mixing that is based on the concept of weak convergence and is capable of probing the "mixedness" at various scales. The particular problem that invention of this measure resolves is the inability of scalar variance ($L^2$ norm of the scalar concentration field) to resolve various stages of contour-level rearangement by chaotic maps. This quantity, that we call a Mix-Norm is a pseudo-norm on the space of scalar fields. We demonstrate the utility of the Mix-Norm by showing how it accurately measures the efficiency of mixing due to diffusion and various point operations. In addition, we apply it for optimization of mixing in a 3-D micromixer flow.

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**MS89**

### Tangles Between Invariant Circles in Volume Preserving Maps

We develop a Melnikov method for volume-preserving maps with codimension one invariant manifolds. The Melnikov function is shown to be related to the volume flux through the unperturbed invariant surface. As an exam-

ple, we compute the Melnikov function for a perturbation of a three-dimensional map that has a heteroclinic connection between a pair of invariant circles. The intersection curves of the manifolds are shown to undergo bifurcations in homology. The Melknikov calculations will be compared with numerical studies of the manifolds and of transport.

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**MS89**

**Barriers to Transport in 3-D Chaotic Flows**

The class of action-action-angle systems is of particular interest within the class of three-dimensional volume-preserving systems since it present behavior drastically different from that in 2-D maps (as shown first in the early work of Feingold, Kadanoff and Piro). It has been shown that Kolmogorov-Arnold-Moser theorem type results generally do not hold for this class. However, we show that a subclass of these maps does admit a KAM-type result that is analogous to the degenerate Hamiltonian case treated by Arnold. The method of proof is different from Arnold's. Despite being non-generic, this subclass of action-action-angle maps is common in applications to mixing of fluids in three dimensions. In this context, we treat an application to the case of a perturbed toroidal vortex structure.

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**MS89**

**Blinking rolls: Chaotic Advection in a 3D Flow with an Invariant**

Chaotic advection of passive scalars can act as an efficient mixing method even when the underlying flow is not turbulent. Here, we discuss a 3D analog of the 2D blinking vortex model of Aref that exhibits complex and chaotic behavior. The fluid motion consists of alternately active 2D rolls acting in different planes. For our system, as in Aref's case, exact solutions of the particle trajectories can be used to explicitly construct a mapping for the system. We will show that when the rolls are orthogonal there is an invariant that prevents full mixing, though two-dimensional mixing occurs. We vary the parameters of the system and study the efficiency of the resulting mixing.

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**MS90**

**Periodic orbits and their invariant manifolds in the Circular Restricted 3-Body Problem**

Periodic solutions of the Circular Restricted 3-Body Problem (CR3BP) have been studied extensively in the literature, with many important contributions. In this talk I will show how boundary value continuation methods such as those implemented in AUTO can be effective tools for studying these orbits and their stable and unstable manifolds. I will show a selection of recent computational results for the families of periodic orbits that originate from the five libration points, and for some secondary and tertiary bifurcating families. I will also show how extended boundary value systems can be used to track loci of these bifurcations. This results in a rather complete classification of the solution structure for all values of the mass-ratio of the primaries. Various aspects of this work have been done in cooperation with Don Dichmann (Torrance CA), Jorge Galan (Sevilla), Randy Paffenroth and Herb Keller (Pasadena), and Andre Vanderbauwhede (Gent).

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**MS90**

**Computing Invariant Manifolds by Integrating Fattened Trajectories**

An invariant manifold in a flow can be defined as a set of trajectories passing through points on a smooth manifold that is transverse to the flow, extending backwards and forward in time. Two adjacent trajectories, with a mesh between, might be used to determine a small strip of the invariant manifold, except for the exponential divergence that is common in "interesting" flows. I will show how to reparameterized the surface along a trajectory so as to factor out the stretching, giving a locally Euclidean quadratic approximation to the surface at each point along the trajectory. This takes the form of an initial value problem involving the point and the derivatives of the surface, which can be integrated with the usual tools. We can calculate an expansion for the unstable manifold near a fixed point, and use it for initial points for integrating these "fattened" trajectories. By selecting an initial point from the boundary of the part of the manifold covered by the fattened trajectory, we can cover the unstable manifold with long trajectories, while avoiding an accumulation of trajectories near the fixed point.

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**MS91**

**Discriminating Linear Correlation and Nonlinear Interdependence by Means of Bivariate Surrogate Techniques**

We applied bivariate surrogate techniques in combination with measures for the characterization of interdependence between deterministic dynamics. The concept of surrogates allows the testing of a specified null hypothesis about the dynamics underlying a given set of time series, such as the assumption of a multivariate linear stochastic process. We show that a combination of interdependency measures with surrogates allows to better differentiate dynamical coupling from linear cross correlation than the exclusive

use of interdependency measures.

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## MS91

### Dimensionality Reconstruction of Coupled Subsystems from Multivariate Data and Application to Space Time Chaos Characterization

We explore an issue that is present when multiple time series are used to reconstruct attractors, namely an algorithmic approach to false nearest neighbors that extends the established one-series method, and allows evaluation of subspace dimensionality for weakly coupled chaotic systems for detection of locally synchronized states. Furthermore, we discuss a possible application of the method, which allows one to introduce an indicator for the characterization of space-time chaotic states in complex space-extended systems.

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## MS91

### Detecting Interrelations Between Time Series Using Randomized Delay Embedding

In the first part of the talk we shall give a brief introductory overview of the task of detecting interrelations in and from time series. Some recently proposed methods will be introduced and we will point out aims and limitations of time series based methods. In the second part of the talk a new method for detecting interrelations will be presented that is based on hypothesis testing for random permutations of delay vectors obtained from the data. Typical features of this method will be demonstrated using different data sets including those provided for this minisymposium.

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## MS91

### Identification of Coupling Direction from Bivariate Data

We consider the problem of experimental detection of directionality of weak coupling between two self-sustained oscillators from bivariate data. Our algorithms provide directionality index that shows whether the coupling between the oscillators is unidirectional or bidirectional and quantifies the asymmetry of bidirectional coupling. We analyse the efficiency of algorithms in determination of directionality index from short and noisy data. The techniques are then applied to the experimental data obtained from two coupled electronic generators and to analysis of cardiorespiratory interaction in healthy infants. With the first application we study the abilities and limitations of the method, analysing different regimes (periodic, two-periodic, chaotic, as well as noise perturbed). With the second application we address an important physiological problem. Namely, we analyze the directionality of coupling between the cardiovascular and respiratory systems in 25 healthy newborns, and study the age and sleep-stage related changes during the first six months of life. The results reveal that cardiorespiratory interaction changes from nearly symmetric during the first days to practically unidirectional (from respiration to the heart rhythm) at the age of six months.

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## MS92

### Emergence of Complex Dynamics in Simple Signaling Networks

A variety of physical, social and biological systems generate complex fluctuations with correlations across multiple time scales. Intriguingly, in physiologic systems these long-range correlations are altered with disease and aging. Such correlated fluctuations in living systems have been attributed to the interaction of multiple control systems, however, the mechanisms underlying this behavior remain unknown. Here, we show that correlated fluctuations characterized by $1/f$ scaling of their power spectra can emerge from networks of simple signaling units. We find that the generation of such long-range correlated time series requires: i) a complex topology with a discrete and sparse number of random link, ii) a restricted set of nonlinear interaction rules, and iii) the presence of noise. Moreover, we find that changes in one or more of these properties leads

to degradation of the correlation properties. These findings may help in elucidating the genesis of complex signals in physiology and their alterations with age and disease.

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**MS92**

**The Dynamics of Proportional Elections**

Nowadays, it has been a matter of increasing interest to apply the fundamentals of the theories of complex systems in many different disciplines, not only in physical sciences, but even in social sciences. The main point is that social systems, like natural ones, are constituted of great number of individuals, which - generally - have local interactions. Elections are processes where many individuals interact between them. It is a dynamical convincing process, where we have at the same time the interaction between neighbours and external influence. In Brazil, proportional elections occur with a large number of voters: the order of magnitudes of millions or tens of millions. So, these elections are a social phenomenon which presents the basic characteristics of complex systems. One of these features is that they are scale-free phenomena. In this work, we introduce a model for electons based on the proposal of scale-free netowrks introduced by Barabasi and Albert. Firstly, we create a network of interactions, where each node is connected to an already connected one, with the probability to connect to a node being proportional to the number of previous nodes which are already connected to it. After preparing the network, we start with the election process, following a Sznajd prescription: only agreeing pairs of people can convince their neighbours. With this model, we recover the same hyperbolic law as found in real elections. Our simulations on a Barabasi network have the advantage that we no longer need special assumptions as introduced previously for the purpose of getting a realistic vote distribution with decay exponent 1 in the center.

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**MS92**

**On the Origin of the Small-world Phenomenon**

The small-world phenomenon in complex networks has been identified as being due to the presence of long-range links, i.e., links connecting nodes that would otherwise be separated by a long node-to-node distance. We find, surprisingly, that many scale-free networks are more sensitive to attacks on short-range than on long-range links. This result, besides its importance concerning network efficiency and/or security, has the striking implication that the small-world property of scale-free networks is mainly due to short-range links.

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**MS92**

**Timing Patterns in Computer Virus Spread**

Analysis of the timing of the arrival of e-mail viruses at different computers provides a way of probing the structural and dynamical properties of the Internet. We found that the intervals, t, between the arrival of 4 different strains of e-mail viruses have a power law distribution proportional to $t^{-d}$, where $1.5 \leq d \leq 3.2$ and that there are positive correlations between these intervals. Salient features of the data were reproduced with a model having subnetwork units of different size where the structural components and the dynamical components all have power law scaling relationships with the size of the units.

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**MS93**

**Dynamics of Two van der Pol Oscillators Coupled via a Bath**

In this work we study a system of two van der Pol oscillators, $x$ and $y$, coupled via a "bath" $z$:

$$\begin{aligned}\ddot{x} &- \epsilon(1-x^2)\dot{x} + x = \gamma(z-x)\\ \ddot{y} &- \epsilon(1-y^2)\dot{y} + y = \gamma(z-y)\\ \dot{z} &= \gamma(x-z) + \gamma(y-z)\end{aligned}$$

We investigate the existence and stability of the in-phase and out-of-phase modes for parameters $\epsilon > 0$ and $\gamma > 0$. To this end we use Floquet theory and numerical integration. Surprisingly, our results show that the out-of-phase mode exists and is stable for a wider range of parameters than is the in-phase mode. This behavior is compared to that of two directly coupled van der Pol oscillators, and it

is shown that the effect of the bath is the reduce the stability of the in-phase mode. We also investigate the occurrence of other periodic motions by using bifurcation theory and the AUTO bifurcation and continuation software package. Our motivation for studying this system comes from the presence of circadian rhythms in the chemistry of the eyes. We present a simplified model of a circadian oscillator which shows that it can be modeled as a van der Pol oscillator. Although there is no direct connection between the two eyes, they can influence each other by affecting the concentration of melatonin in the bloodstream, which is represented by the bath in our model.

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### MS93

### The Community Structure of Networks

A number of recent studies have focused on the statistical properties of networked systems such as social networks and the World-Wide Web. Researchers have concentrated particularly on a few properties which seem to be common to many networks: the small-world property, power-law degree distributions, and network transitivity. Here, we highlight another property which is found in many networks, the property of community structure, in which network nodes are joined together in tightly-knit groups between which there are only looser connections. We propose a new method for detecting such communities, built around the idea of using centrality indices to find community boundaries. We test our method on computer generated and real-world graphs whose community structure is already known, and find that it detects this known structure with high sensitivity and reliability. We also apply the method to two networks whose community structure is not well-known - a collaboration network and a food web - and find that it detects significant and informative community divisions in both cases.

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### MS93

### Modulated Amplitude Waves in Bose-Einstein Condensates

We analyze spatio-temporal structures in the cubic and cubic-quintic nonlinear Schrödinger equations in order to study the dynamics of quasi-one-dimensional Bose-Einstein condensates with mean-field interactions. With this ansatz, one obtains a Duffing-like oscillator (for the spatial variable), which is unforced in the absence of an external potential and forced in the presence of one. When the (two-body) scattering length is small, we apply Lindstedt's method to determine the dependence of the amplitude on the wavenumber of periodic orbits (modulated amplitude waves) for both the cubic and cubic-quintic cases. We also apply a linear stability analysis to the forced case and simulate the ordinary differential equations that must be satisfied for the coherent structure ansatz to be valid. Using a multiple timescale perturbation analysis, we investigate the period-amplitude dependence of modulated amplitude waves in the presence of an external potential. We consider in particular two potentials of experimental interest: a periodic potential and a wiggling harmonic potential. Finally, we discuss future problems that can be addressed with this recasting of Bose-Einstein condensation as a forced nonlinear oscillator problem.

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### MS93

### Approximating a Time Delay in Coupled van der Pol Oscillators

This work examines the dynamics of two weakly coupled van der Pol oscillators in which the velocity coupling terms have a time delay. Previous studies have shown that approximating the delay terms via a Taylor series expansion of the averaged equations yields analytical results that are in good agreement with the numerical integration of the original equations, given suitable restrictions on the parameters. This current work examines the averaged equations before they have been Taylor expanded and then investigates the stability and bifurcation of their equilibria. The results are compared with those obtained with the Taylor series truncation and the validity of the original results is examined. The study of these equations is motivated by applications to laser dynamics and the coupling of microwave oscillators.

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### MS94

### Macroscopic Equations for Chemotaxis in Systems with Internal State Variables

We consider the velocity jump process of individuals (e.g. bacteria) where each individual has its internal state (e.g. concentration of chemicals inside the cell) evolving according to a system of ordinary differential equation. The velocity jump process has its parameters dependent on the response of the internal dynamics. Using moment closure techniques, we derive a system of hyperbolic partial differential equations describing this process. We analyse the resulting system, and we apply our results to bacterial chemotaxis. We also show how to obtain the classical chemotaxis equation from this system.

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**MS94**

**Blow-up in Hyperbolic Models for Chemotaxis**

Since the work of Jaeger and Luckhaus (1992) the mathematical analysis of finite time blow-up in chemotaxis models has flourished. As most authors consider the classical Keller-Segel model, the question arose if hyperbolic models, which base on velocity jump processes, show the same phenomenon. In my talk I present co-work with H. Levine (Iowa) about finite time blow-up solutions of a hyperbolic chemotaxis model. I will compare these results to the classical case with emphasis on differences in blow-up times. I will discuss the relevance for applications.

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**MS94**

**Pseudostructures: Ultra-long Transients in Chemotaxis Model**

We consider a chemotaxis model with the chemotaxis coefficient vanishing at high population density. We study the very long transient processes observed in this model earlier. The profiles of concentration almost freeze for quite a long time, then relatively quickly the profile transforms to another one and freezes again. We called these formations "pseudostructures". In experiments it may be very hard to distinguish pseudostructires and true stationary structures. We show that the existence time for these pseudostructures exponentially grows with the size of the system.

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**MS94**

**Aggregation in Keller-Segel Models**

Abstract not available at time of publication.

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**MS95**

**Controlling Turbulence and Pattern Formation in a Surface Chemical Reaction**

Experiments with the catalytic oxidation of carbon monoxide on Pt(110) show that chemical turbulence in this system can be controlled by the application of global delayed feedback schemes or external periodic forcing. The question of invasiveness of global feedback and aspects of stability of the controlled state are addressed in a theoretical study of the time-delay autosynchronization feedback scheme. Near the feedback induced transition from turbulence to uniform oscillations, we observe in the experiment a variety of spatiotemporal patterns like intermittent turbulence, oscillatory standing waves, cellular structures, and phase clusters. The experimental results are compared to numerical simulations of a realistic model of catalytic CO oxidation on Pt(110) with global delayed feedback and analyzed in terms of a representation in phase and amplitude variables derived by a method based on the Hilbert transform. A similar wealth of spatiotemporal patterns is observed in an experimental study, investigating the effect of time-periodic, spatially uniform external forcing on chemical turbulence in the catalytic CO oxidation.

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**MS95**

**Cluster Formation and Localization in the Globally Forced BZ Reaction and Other Reaction-Diffusion Systems**

Localized oscillatory cluster patterns and other complex pattern formation phenomena (e.g., Turing structures, standing waves, spirals and antispirals) are found in experiments on the Belousov-Zhabotinsky reaction in two configurations: a) with a photochemically induced global feedback, and b) in a water-in-oil microemulsion. Computer simulations of models that take into account both the chemistry and either the photochemical feedback or the differential diffusion that occurs in the microemulsion yield results in excellent agreement with the experiments.

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**MS95**

**Modulation Equations for Localized Patterns Away from Criticality**

Modulation equations describe the behavior of complex systems over long scales. However, their validity is often limited to near-criticality. A new multiscale approach, combining energy arguments and balance of nonlinearities, yields modulation equations for localized buckling of a strut away from the critical load, where standard asymptotics and normal forms fail. Immediate connections to heterogeneous patterns in other applications are shown. The approach is illustrated via simple one-dimensional models, motivated by numerics and experiments.

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**MS95**

**Localization of Oscillations in a Mathematical Model of the BZ Reaction**

Motivated by experimental results on localization in the Belousov-Zhabotinsky reaction with global inhibitory feedback, we study a mechanism of localization in a discrete system of globally coupled relaxation oscillators of FitzHugh-Nagumo type. The mechanism is based on the canard phenomenon. We show that by increasing a global-feedback parameter, and mostly due to self-inhibition, the

system becomes organized into two oscillatory clusters with well differentiated amplitudes. We extend our results to Oregonator models for the Belousov-Zhabotinsky reaction.

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**MS96**

**Response Dynamics and Phase Oscillators in the Brainstem**

We describe a model of activity in a brainstem nucleus during different cognitive tasks. Extracellular recordings from this nucleus show varying responses dependent on its baseline firing rate and synchrony, which are correlated with level of task performance. From conductance equations, we derive a phase oscillator model and study the resulting coupled stochastic dynamics. A probability density formulation demonstrates the contribution of baseline firing rate and stimulus duration to the observed response variability.

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**MS96**

**Dendritic Hysteresis Increases the Robustness of Fixations in a Model Neural Integrator**

The oculomotor neural integrator converts velocity-coded eye movement commands into eye position signals. In the absence of velocity commands, integrator neurons maintain a steady rate of firing for tens of seconds. To achieve these long persistence times, most models use neurons with a continuous firing rate vs. injected current relationship and precisely tuned positive feedback. Bistability in neuronal responses has been proposed as a mechanism to maintain persistent activity. However, neuronal bistability tends to produce a large discontinuity in firing rate responses, contradicting the experimentally observed threshold linear relationship between firing rates and eye position. We show how dendritic bistability can enhance the robustness of eye fixations to mistuning while preserving the threshold linear firing rate relationship. We analytically model a network in which the firing rate of each neuron is a linear sum of the contributions from multiple bistable dendritic compartments, plus tonic background and external velocity-command inputs. The networks tolerance to mistuning is related to the range of bistability of the dendritic compartments and to the slopes and thresholds of the neurons firing rate vs. eye position relationships. Severe mistuning leads to approximately exponential decay towards a nonzero null eye position, in agreement with experimental observation. The model response to continuously varying inputs leads to testable predictions for the performance of the vestibulo-ocular reflex.

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**MS96**

**Synchronization in Globally Inhibitory Networks: Modeling the Sharp Wave-associated Ripple**

The *sharp wave-associated ripple* is a high-frequency ($\sim$ 200Hz), transient ($\sim$ 100msec duration), extracellular field oscillation recorded from the CA1 region of the hippocampus. It is observed during slow-wave sleep and periods of behavioral immobility, and has been implicated in such processes as memory consolidation and memory transfer. Through a little understood process, the CA1 pyramidal cells rapidly synchronize in time during the ripple. A small, idealized representation of the CA1 region is used to propose a mechanism for fast synchronization, involving interneuron-pyramidal cell cooperation. Geometric, singular perturbation techniques in the phase plane are invoked, proving that a stable, synchronous solution exists if the applied inhibition is increased from low to high frequency, as seen during the ripple. Depressing, inhibitory synapses are shown to be crucial to this result, initially suppressing then releasing the pyramidal cells.

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**MS96**

**Coupling within Oscillatory Networks: Theory and Experiment**

Oscillatory activity is found at all levels of the nervous system and is associated with such diverse functions as respiration, locomotion, sensory perception, and attention, as well as pathological conditions such as epilepsy and Parkinson's disease. In efforts to understand the nature of these oscillatory networks one important question is how oscillatory activity is synchronized across multiple regions of the brain. We have addressed this problem in a simple vertebrate system, the locomotor central pattern generator in the lamprey spinal cord. Movement in vertebrates involves precise coordination between body segments. It has been suggested that such coordination results from interactions between segmental oscillators along the length of the spinal cord. We have used a mathematical theory of coupled oscillators to investigate this intersegmental coordination. Mathematical analysis provided a number of experimentally testable predictions regarding the nature of the coupling underlying this coordination. The experimental results then provided new insights into the properties of the coupling necessary to provide the appropriate phase relationships between oscillators and new constraints for

our theoretical investigations of coupling in oscillatory networks.

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**MS97**

**Probing a Chaotic Channel by Means of Signal Control**

Work on ray chaos, particularly in acoustics has led to an understanding of limitations on the range possible with conventional systems in a waveguide. There has been recent interest in the use of chaotic signals in radar and sonar, and this talk will explore the interaction between a chaotic signal and a spatially chaotic channel. The possibility of using time bifurcation as a further means of characterising behaviour in the spatially chaotic region by means of feedback transmit-receive control system will be considered.

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**MS97**

**Vibro-Impact Systems Dynamics**

Vibro-impact systems are inherently nonlinear and have been widely used in civil and mechanical engineering applications. One may give examples of ground moling machines, percussive drilling, ultrasonic machining and mechanical processing. It is widely accepted that almost all design of new engineering systems operating in dynamic regimes will use some nonlinear interactions between the systems components. The vibro-impact systems are no exceptions and due to their strong nonlinearities, a detailed dynamic analysis is required to gain a good understanding how the structural and control parameters can be used to enhance the system performance. During the presentation after a brief introduction to dynamical systems with motion dependent discontinuties [1] and two case studies will presented: (i) dynamics and control of a vibro-impact ground moling system [2, 3] and (ii) vibration enhanced drilling. An account on the conducted experimental studies, mathematical modelling and analysis of the simple models mimicking those two problems will be given. For those models, which use some new concepts of vibrational energy transfer via modulated impacts, we have developed highly effective semi-analytical solution allowing to determine the optimal operational conditions.

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**MS97**

**Nonlinear Dynamics and Control of Jeffcott Rotor**

The nonlinear vibrations and their control via an electrorheological (ER) damper are considered in a rotor system subjected to an out-of-balance excitation. The model, which is similar to a Jeffcott rotor, assumes a situation where gyroscopic forces are neglected, and concentrates on the dynamic responses caused by interactions between a whirling rotor and a massless snubber, which has much higher stiffness than the rotor. The system is modelled by two second order differential equations, which are linear for non-contact and strongly nonlinear for contact scenarios. The viscous damping is actively changed to influence the system responses, in particular in the nonlinear regions. The study involves mathematical modelling and experimental verification on a test rig, where the ER damper has been installed to vary viscous damping for one of two degrees-of-freedom, with which the Jeffcott rotor can be approximated. The experimental data has been captured using a LabView platform. The theoretical analysis has been carried out by newly develop robust approximate analytical methods. The first and the simpler method has been named one point approximation (1PA) is suitable for soft impacts and gives a reasonable prediction of responses ranging from period one to period four motion. The second and more accurate method of multiple point approximation (MPA) expands the nonlinear term many times when the rotor and the snubber ring are in contact and it can even be used for calculating chaotic responses. The methods are evaluated by a comparison with direct numerical integration showing an excellent accuracy. A suite of nonlinear dynamics analysis techniques such as constructing bifurcation diagrams, Poincare maps, Lyapunov exponents and basin of attractions has been also employed to investigate the global dynamics of the system . An extensive study encompassing the effects of different system parameters, particularly the changeable damping from the ER damper, in order to demonstrate the severity of the vibrations will presented. It is also shown that the response of the system can be extremely sensitive to changes in these parameters, and that chaos can exist over large regions of parameter space. The control using the ER damper has proved to be very effective for the parameters where multiple attractors co-exist.

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**MS97**

**Harmonic Balance and Phase Shift Adjustment in Ground Moling**

To address the issues related to the development of a robust and adequate model of vibro-impact machines operating in soil, the incremental harmonic balance method, involving the perturbation of state variables, is applied to a model describing stiffness, damping and stick-slip characteristics. This model has been refined by de-coupling the equations of motion. Periodic solutions are sought and these aid design procedures by allowing for the identification of system parameters for the optimum soil penetration rate.

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**MS98**

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To Be Announced

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**MS98**

**Effective Adaptive Sampling of Mega-Dimensional Chaos**

The world economy wagers substantial amounts of money and health on the accuracy of oceanic and atmospheric weather forecasts. Estimation theory shows how the accuracy of these forecasts is constrained by when and where observations are taken. Adaptive sampling techniques estimate which of all feasible future observational networks would minimize forecast error variance. The talk will review recent advances in adaptive sampling, point out the crudeness of these "advanced techniques" and challenge the audience to find more satisfactory approaches.

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**MS98**

**Atmospheric Data Assimilation: New Kalman-Filtering Techniques Using Ensembles**

We consider the process of determining initial conditions for a weather forecast model. Kalman filtering provides a conceptually straightforward way of approaching this problem, but due to the high dimensionality of the state vector, such techniques are computationally infeasible. We discuss new, simplified versions of the Kalman filter that estimate error covariances using ensembles of forecasts, and we compare the results of these techniques with current, operational techniques.

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**MS98**

**Exploiting Local Low Dimensionality of Atmospheric Dynamics for Efficient Ensemble Kalman Filtering**

Recent studies have shown that, when the Earth's surface is divided up into local regions of moderate size, vectors of the forecast uncertainties in such regions tend to lie in a subspace of much lower dimension than that of the full atmospheric state vector. We show how this finding can be exploited to formulate a potentially accurate and efficient data assimilation technique that is amenable to massively parallel computation using relatively low dimensional matrix calculations.

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**MS99**

**Weak Turbulence and the Stages of Energy Transfer in $\alpha$-FPU**

We shall discuss $\alpha$-FPU in the context for which it was originally developed: as a model for the evolution to thermodynamic equilibrium of large discrete systems. The weak nonlinearity, $\alpha$, allows for energy transfer between the waves through resonant interactions. In the $\alpha-$ FPU model we consider, the non-linearity transfers energy primarily through 3-wave interactions: two waves of wavenumber $k_1$, $k_2$ interact to drive the wave $k = k_1 + k_2$ if $\omega(k) = \omega(k_1) + \omega(k_2)$. Though no exact three wave resonances exist in general for FPU, a careful application of weak turbulence theory nonetheless predicts an equipartition of energy (the second cumulant) in a wavenumber band $\sim \alpha^{1/2}$ on timescales $\sim \alpha^{-3/2}$. Numerical simulations bear out these predictions and further provide the third and fourth cumulants to compare with weak turbulence closure predictions.

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**MS99**

**Transitions and Time Scales to Equipartition in Oscillator Chains: from the FPU to the Klein-Gordon chain**

We compare the time scales to equipartition $T_{eq}$ in two oscillator chains: the discretized Klein-Gordon equation with a quartic nonlinearity( $\varphi^4$ system) and the Fermi-Pasta-Ulam oscillator chain with quartic nonlinearity (FPU-$\beta$ system). The outline the methods originally developed by us to estimate the equipartition times for the FPU$-\beta$ chain (*Phys. Rev. E* **60**, 3781 (1999) ) and later extended to the $\varphi^4$ chain (*Phys. Rev. E* **66**, 026206, (2002)), with focus on low-frequency initial conditions. For the two cases there is an energy density region where $T_{eq}$ can be approximated by a power law, $T_{eq} \propto (E/N)^p$, but for the $\varphi^4$ chain with $m > 1$ the transition between power-law and exponential behavior is not as clear as for the FPU chain, where the critical energy density is zero ($E_c/N \to 0$ when $N \to \infty$) (*Chaos* **5**, 283 (1995)). Last we show some numerical evidence for lack of equipartition at a finite energy density in the $\varphi^4$chain with $m > 1$.

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**MS99**

**Symplectic Structure of FPU Equations and Global-in-time Stability of Solitary Waves**

Abstract not available at time of publication.

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**MS99**

**Simulating Disordered Extended Lattice Systems on Finite Domain**

The dynamics of weakly nonlinear dispersive wave systems such as the FPU lattice will have significant differences from its ideal extended thermodynamic limit when simulated on even a moderately large but finite periodic domain. We explore how finite size artifacts may be removed through randomization of the boundary conditions.

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**MS100**

**Normal Form Theory and Asymptotics for Weakly Nonlinear ODE's**

Asymptotic techniques such as the method of multiple scales, averaging theory, the Poincare-Lindstedt method, boundary layer theory, and many others, have been devised to deal with secularities that may arise in regular perturbation expansions of differential equations with a small parameter. The renormalization group technique has had success in unifying several of these seemingly disparate methods. In this talk, we discuss an asymptotic method, called the method of normal forms, that shows similar promise for dealing with a wide array of perturbation problems in a unified framework. In addition, the long time approximations provided by the normal form method can be rigorously justified in many instances. We will also explain how the resonance conditions of normal form theory are related to the renormalization group technique.

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**MS100**

**Renormalization Method for the Asymptotic Solution of Weakly Nonlinear Vector Systems**

Abstract not available at time of publication.

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**MS100**

**Renormalization and Geostrophic Asymptotics in Geophysical Fluid Dynamics**

We present a framework in which the techniques of renormalization can be applied to derive useful information about qualitative as well as quantitative behaviour of geophysical models in certain limiting cases, such as the Rossby number being small. In addition, we show how the conventional geophysical approximations fit in this framework. The asymptotic limitations of these approaches will be discussed.

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**MS101**

**Effects of Rotation and Lorentz Forces on Turbulent Geophysical Flows**

Realistic parameter values for geophysical flows in the core and atmosphere yield turbulent flows. These flows also have significant order placed by the effects of rotation, and for core flows, Lorentz forces. This talk will discuss some present understanding of these ordering effects, and will show experimental observations of associated laboratory flows. The experimental flows include rotating convection and flows in liquid metals where magnetic fields significantly alter and simplify the observed patterns.

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**MS101**

**Multiscale Variability of Shear Stratified Turbulence Around A Jet Stream**

There are few reliable results on the characterization of outer scales of turbulence in the remote atmosphere and their dependence on the background atmospheric conditions (stability and jet stream profile). Knowledge of the variability of turbulence outer scales and the refractive index structure parameter, is of fundamental importance in understanding atmospheric processes as well as optical propagation in the atmosphere. High resolution direct numerical simulations on massively parallel machines are performed to study the dynamics of an inhomogeneous stratified shear flow for a jet stream in the tropopause.

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**MS101**

**Competing Theoretical Frameworks for Atmospheric Variability: Quasi-geostrophic Turbulence vs Linear Stochastic Dynamics**

The standard explanation of atmospheric patterns of variability has relied upon the dynamical systems paradigm of successive bifurcations from laminar stationary states, to low order chaos and on to high dimensional turbulence. This view has been challenged and an alternative explanation has been proposed in which transient atmospheric patterns result from random forcing. The background flow is stable and no bifurcation occurs. I examine numerical experiments to determine which paradigm best fits atmospheric variability.

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**MS101**

**Moist Convection in a Three Layer Shallow Water Model**

A simplified dynamical system consisting of three coupled constant density shallow water layers has been developed, along with a representation of moist convection. The thermodynamics is represented through mass source/sink terms for each layer with the interfacial fluxes specified in terms of conservation of moist entropy in the boundary

layer and moist static energy in the column above. This model has been applied to the genesis of tropical cyclones and to examine the large scale response of the tropical atmosphere to sea surface temperature anomalies.

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**MS102**

**Some Applications of Low-dimensional Manifolds to Problems in Chemical Kinetics**

A common way to extract rate constants and relaxation behavior from the microscopic properties of molecular dynamics is through the asymptotic dynamics of master equations. Two examples of the asymptotic behavior of nonlinear master equations are discussed, where the dynamics of the systems approach one-dimensional manifolds. An additional application to reaction-diffusion equations for elementary reactions will be discussed.

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**MS102**

**Analysis of Multidimensional Reacting Flow with CSP**

The analysis of multidimensional computational reacting flow data involves significant challenges pertaining to the large dimensionality and stiffness of the chemistry, and to transport-chemistry coupling. We have used Computational Singular Perturbation (CSP) theory for the analysis of computed two-dimensional premixed flame-vortex interaction, with C1-C2 methane-air kinetics. This talk will focus on the implementation of CSP in this context and on the analysis results, which enable both improved understanding of the flow and automatic chemical reduction.

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**MS102**

**Qualitative Applications of Invariant Manifold Theory in Biochemical Modeling**

Direct calculations of invariant manifolds tell us how one variable (e.g. a concentration) responds to changes in another. The process can be inverted: We can take a skeletal model and say how the variables have to depend on each other to obtain a particular behavior. Given this knowledge, we can sometimes construct plausible chemical reaction steps achieving a particular modeling objective. This qualitative use of invariant manifold theory will be explained through biochemical examples.

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**MS102**

**Low Dimension Manifolds for Aggregation Kinetics: An Alternative to Scaling Theories**

The growth of domains (or clusters) in systems exhibiting phase transition has traditionally been modeled using either brute force Monte Carlo simulation or through scaling theories. Scaling theories are attractive in that they can yield cluster distributions and growth laws with minimal information about the energetics of the atomic level processes. Here, the use of low dimension manifolds is discussed as a more accurate and useful alternative to scaling theory to obtain the rate laws for cluster growth. This work is done in collaboration with Michael J. Davis and David Brunelli

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**MS102**

**The Reduction of Complex Atmospheric Chemical Models Using Time-Scale Based**

Atmospheric models for the accurate prediction of pollutant formation on global, regional and urban scales require the inclusion of complex nonlinear chemical mechanisms involving many coupled species with a wide range of atmospheric lifetimes. Methods are therefore required to reduce the burden of the chemical sub-component within reactive flow models. This paper will discuss the use of time-scale based methods such as low dimensional manifolds and species lumping for mechanism reduction. The methods will be demonstrated with application to highly detailed atmospheric mechanisms such as the Master Chemical Mechanism (MCM).

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**MS103**

**Experiments and Numerical Studies of 3-D Chaotic Flows in a Micromixer**

We present an experimental and numerical study of mixing in three-dimensional flow in an actively controlled micromixer. The geometry consists of a main channel with three transverse channels by which transverse momentum is imparted on a fluid. We apply a nonperiodic mixing protocol to mix two miscible fluids within a small length/width ratio. We characterize the mechanism of mixing from the dynamical systems perspective and discuss change of mixing properties with scales of observation.

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**MS103**
**Mixing and Transport in Taylor Couette Flows**

The Taylor Couette system of shear flow between a rotating inner cylinder and a concentric, fixed outer cylinder is a canonical system that provides valuable insight into low-dimension bifurcation phenomena and chaotic mixing. Above a critical Reynolds number, the unstable flow consists of independent toroidal vortices stacked axially in the annulus. No mixing between vortices occurs and inertial particles in the flow tend toward a limit cycle orbit within individual vortices. At somewhat higher Reynolds numbers, the toroidal vortices become wavy. They are characterized by deformation of the vortices both radially and axially with two to six waves around the annulus. Significant transfer of fluid between vortices occurs in a cyclic fashion at certain points along the azimuthal wave, so that while one vortex grows in size, two adjacent vortices become smaller, and vice versa. This results in an alternating net upward and downward flow in axial bands corresponding to the azimuthal waves. Computationally tracking fluid particles in an experimentally obtained three-dimensional, three-component velocity field for wavy vortex flow provides information about the nature of the transport. Mixing increases with increasing Reynolds number because of increased folding and stretching in meridional, latitudinal, and circumferential surfaces. As a result of the chaotic mixing, the axial transport within and between vortices is enhanced compared to nonwavy vortex flow. The effective dispersion coefficient calculated from the particle tracking is very similar to that found experimentally and computationally confirming that chaotic advection is the mechanism responsible for enhanced mixing in wavy vortex flow. [Funded by NSF]

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**MS103**
**3D Flow Instabilities in Granular Suspensions**

We report the spontaneous emergence of a three dimensional train of sedimented knolls in a dense suspension. These solidified knolls rise out of, and coexist alongside, a sea of freely flowing liquid in a slowly rotating horizontal bottle. We apply a variable viscosity model that permits simultaneous analysis of fluid-like and solid-like behaviors that are ubiquitous in a variety of sedimenting flows. The model generates qualitative agreement with experiment, and produces new insights into mechanisms by which instabilities can impart their effects on 3D patterns over long distances.

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**MS103**
**Experimental Studies of Chaotic Mixing in Vortex Flows**

We present results of experimental and numerical studies of chaotic advection in cellular flows. One system is an oscillating (time-periodic) vortex chain, a flow that would be two-dimensional (2-D) except for a secondary flow due to Ekman pumping that carries fluid inward along the bottom and up through the vortex centers. We investigate the effects of this secondary, 3-D flow on the invariant tori that act as transport barriers for the strictly 2-D flow (in the absence of the secondary flow). Another flow studied is a time-independent, 3-D flow composed of the superposition of horizontal and vertical vortex chains, phase shifted by one-half of a vortex width. Transport in this system is dominated by trajectories referred to as Levy flights in which tracers jump long distances between distant vortices. The resulting transport is superdiffusive where the variance of a distribution grows linearly with time. Experiments are also being done to study the effects of chaotic advection on dynamical processes occurring in these vortex flows; specifically, we are studying chaotic advection as a coupling mechanism in a network of chemical oscillators, as well as the effects of chaotic motion on the stretching and breakup of drops advected in the flow.

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**MS103**
**Experimental and Computational Studies of Chaotic Mixing in 3D vortical flows**

I will review recent progress in experimental and computational studies of complex chaotically advected 3D flows. Results will be presented for two cases: a confined swirling flow with vortex breakdown and an open flow in a helical static mixer. For the former case, I will present computational and experimental evidence suggesting that increasing swirl intensity (ratio of characteristic azimuthal to axial velocities) can stabilize chaotic orbits and lead to quasi-periodic dynamics. For the helical mixer case, numerical simulations show that above a threshold Reynolds number unmixed islands appear in the flow. I will discuss the mechanism that leads to the formation of such islands and argue that it is linked to the growth of coherent helical vortices in the flow.

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**MS104**

**Dynamics and Control of Underwater Gliders**

Underwater gliders are buoyancy-propelled, winged submersibles with attitude controlled by means of active internal mass redistribution. Like dolphins and seals, gliders move with little effort if made to follow steady glide paths. With active buoyancy control for gliding up as well as down and wings for lift and maneuverability, gliders move easily along sawtooth trajectories and can also turn in ascent and descent. I will present simple dynamic models of underwater gliders which capture some of the hydrodynamic forces, the active buoyancy control and the coupling between the vehicle and the movable internal mass. I will discuss underwater glider dynamics and control and show some results from underwater glider experiments at sea.

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**MS104**

**Variational Integrators for Interacting Point Vortices**

We develop discrete mechanics and variational integrators for a class of degenerate Lagrangian systems that includes systems of point vortices. Excellent numerical behavior is observed. A longer term goal is to use these integration methods in the context of control of mechanical systems, such as coordinated groups of underwater vehicles. In fact, numerical evidence given in related problems shows that even in the presence of external forces, these methods give superior predictions of energy behavior.

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**MS104**

**Efficient Navigation Routes: Utilizing the Natural Dynamics of the Ocean**

Contour plots of Finite-Time Direct Lyapunov Exponents (DLE) can be very helpful for revealing the global geometry of general time-dependent flows. Extrema in DLE contours delineate Lagrangian Coherent Structures, which often approximate stable and unstable manifolds. Studying these scalar DLE fields has often been used to help understand mixing and transport in complex flows. We extend the application of DLE to navigation planning and adaptive sampling. With the help of DLE computations, we develop efficient control and navigation schemes for groups of autonomous underwater gliders used to perform adaptive oceanographic sampling.

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**MS104**

**Vortex Wakes of Flying Birds**

When the motion and geometry of the force-producing surfaces is complicated, as is often the case in animal flight, then simple models of the vortex wake can assist in inferring their aerodynamic properties. This requires (i) Correct information about the wake structure, and (ii), some minimum degree of simplicity/coherence in it. The existing state of the art will be examined, found to be be far from satisfactory, and recommendations for progress will be made.

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**MS104**

**Effects of Nonlinearity and Vorticity in Locomotion of Aquatic Animals**

The effects of nonlinearity and vorticity production in the locomotion of aquatic animals will be addressed for the case of high Reynolds numbers, as in swimming of fishes and cetaceans, and for low Reynolds numbers, as in the self propulsion of ciliates and flagellates. The nonlinear effects to be explored for high Reynolds numbers will include that due to motions along arbitrary trajectories and arbitrary amplitude in the presence of vortex sheets shed from appended fins. For low-Reynolds-number case with the inertial effects overwhelmed by viscous effects, the concept of swift diffusion of vorticity generated by applied forces will be discussed under the premise of self-propulsion.

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**MS105**

**Relative Dispersion in Fully Developed Turbulence**

The statistics of relative dispersion in fully developed turbulence is studied by means of direct numerical simulations. The results are compatible with the original Richardson description based on a diffusion equation. The value of the Richardson constant is estimated $C_2 \simeq 0.55$, in close agreement with recent experimental findings. By using an exit time statistics, small deviations from self-similarity in Lagrangian probability distributions are detected. These deviations, signature of Lagrangian intermittency, are described by an extension of the multifractal model to Lagrangian statistics.

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**MS105**

**Decay of Scalar Turbulence Revisited**

We demonstrate that at long times the rate of passive scalar decay in a turbulent, or simply chaotic, flow is dominated by regions (in real space or in inverse space) where mixing is less efficient. We examine two situations. The first is of a spatially homogeneous stationary turbulent flow with both viscous and inertial scales present. It is shown that at large times scalar fluctuations decay algebraically in time at all spatial scales (particularly in the viscous range, where the velocity is smooth). The second example explains chaotic stationary flow in a disk/pipe. The boundary region of the flow controls the long-time decay, which is algebraic at some transient times, but becomes exponential, with the decay rate dependent on the scalar diffusion coefficient, at

longer times.

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**MS105**

**Homogenization of Gravity Currents in Porous Media**

We explore the problem of a slumping gravity current in the presence of a variable coefficient porous medium. We identify similarity variables and solutions for the constant coefficient case, and, using methods of homogenized averaging generalized to this nonlinear problem involving a moving boundary condition, make a connection to these similarity scalings in the case of variable coefficient layered media. We utilize these similarity scalings to identify half-height slumping time scales as a rough guide for field groundwater cleanup strategies involving injected salt water. By simplifying to a thin gravity current, retaining variations of the porous media in the horizontal direction, we derive a variable coefficient scalar nonlinear partial differential equation governing the moving interfaces. Through a combination of explicit homogenization retaining leading-order plus first-order corrections, and comparison with the full simulation of this simplified one-dimensional problem, we document the success of the homogenization approach for this nonlinear problem. In the context of a thin gravity current we also numerically address a case where the background permeability variation is in the vertical direction. The corrections identified exhibit a spatial imprint of the properties of the porous medium. Lastly, we provide a leading-order homogenization solution for the general case where permeability varies in both the horizontal and vertical dimensions, which results in coefficients that are accessible through the solution of a cell problem.

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**MS105**

**Inertial Particles in a Random Field**

The motion of inertial particles in a turbulent velocity field is a problem of great interest in various fields of science and engineering. A mathematical model which comprises Stokes's law for the particle motion and an infinite dimensional Ornstein-Uhlenbeck process for the velocity field was recently proposed and analyzed by Stuart et al. 2002. In this talk we review the basic mathematical properties of this model within the framework of the theory of random dynamical systems and study various scaling limits of physical interest. In particular, we prove that the long time behavior of the inertial particles when the fluid is rapidly decorrelating in time is described by a system of stochastic differential equations, the convergence being strong in $L^2(\Omega, C([0,T], \mathbf{R}))$. We also discuss our convergence theorems in the light of recent work on stochastic mode elimination.

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**MS105**

**Intermittency in Passive Scalar Decay**

We consider the decay of a passive scalar in a rough turbulent flow. We show that at large times the scalar intensity is statistically equivalent to the product of two independent random variables. The first factor is a Gaussian variable related to the typical fluctuation at initial conditions. The second factor is essentially the probability that, in a given realization of the flow, tracer particles separate at a very slow rate. Therefore, the large-time scalar distribution is always broader than Gaussian for any initial condition, and large scalar excursions are associated to small relative dispersion events.

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**MS105**

**Lagrangian Properties of 2D and 3D Quasi-geostrophic Turbulence**

The large-scale motion of atmospheres and oceans is governed by the quasigeostrophic equations. Both 2D and 3D quasigeostrophic turbulence self-organize into coherent vortices which dominate the flow. Here we compare the transport properties of these flows. We find that there are many similarities, and that the differences are related to the different ranges of vortex interaction in 2D and 3D.

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**MS106**

**Working Memory in Networks of Spiking Neurons**

Analytical methods that allow characterization of the asynchronous states of networks of irregularly firing neurons will be presented. Using these methods, several scenarios for network bi- or multi-stability will be discussed. These scenarios will be compared with available electrophysiological data on awake monkeys.

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**MS106**

**Dynamics of a Recurrent Network with Synaptic Failure and Hidden Neurons**

We study networks of all-to-all coupled, integrate-and-fire, excitatory neurons, with a portion of the population receiving feedforward drive and the remaining, "hidden", por-

tion receiving no feedforward input. We demonstrate that this system undergoes a subcritical bifurcation as either the input or recurrent coupling is varied. Because of this transition, the network gates feedforward inputs and exhibits bistability and hysteresis. The hidden population allows this network response to be continuously tunable in the forcing and coupling strengths. Furthermore, these features persist in the presence of synaptic failure and for small network sizes, suggesting that the computations discussed here could be implemented in biological networks. Finally, we demonstrate that a long network correlation, orders of magnitude longer than the synaptic time, emerges from the recurrent coupling. This correlation time scales with network size and with synaptic connection probability.

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### MS106

### Simple and Complex Cells in a Mean-Field Model of the Visual Cortex

Neurons in the primary visual cortex are classified as Simple or Complex, depending how linearly they respond to visual stimuli. Simple cells respond in an approximately linear fashion and Complex cells are very nonlinear. These responses may have different tasks in visual processing. I will discuss the development of coarse-grained models of the visual cortex to the understanding of how Simple and Complex cells can emerge from a single circuit. The reduced system is used to study the response of neurons to drifting grating stimuli and captures the dynamics of neuronal network at larger space- and time-scales.

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### MS106

### Mexican Hats and Pinwheels in Visual Cortex

Many models of cortical function assume that local lateral connections are specific with respect to the preferred features of the interacting cells and that they are organized in a Mexican-hat pattern with strong center excitation flanked by strong surround inhibition. However, anatomical data on primary visual cortex (V1) indicate that the local connections are isotropic and that inhibition has a shorter range than excitation. We address this issue in an analytical study of a neuronal network model of the local cortical circuit in V1. In the model the orientation columns specified by the convergent LGN inputs are arranged in a pinwheel architecture, whereas cortical connections are isotropic. We obtain a trade-off between the spatial range of inhibition and its time constant. If inhibition is fast, the network can operate in a Mexican-hat pattern with isotropic connections even with a spatially narrow inhibition. If inhibition is not fast, Mexican-hat operation requires a spatially broad inhibition. The Mexican-hat operation can generate a sharp orientation tuning which is largely independent of the distance of the cell from the pinwheel center.

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### MS106

### Scale-up of Visual Cortex Modelling

The visual cortex, in its processing of visual stimuli, operates on many space- and time-scales and on both ordered and disordered feature maps. I will discuss the development and application of coarse-grained models of neuronal networks to understanding the dynamics of the visual cortex, its selectivities such as for orientation and spatial phase, and for understanding how Simple and Complex cells can emerge from a single circuit. Such reductions capture the dynamics of neuronal assemblies at larger space- and/or time-scales by exploiting the averaging nature of cortico-cortical interactions and the development of time-scale separation during stimulation.

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### MS106

### Simple and Complex Cells in Primary Visual Cortex

Orientationally selective neurons in the primary visual cortex (V1) are generally separated into two broad classes: those that show approximately linear responses (Simple cells) and those that do not (Complex cells). These response differences may underlie important functional differences in visual processing, and yet there has been no satisfactory explanation of how these differences arise within the cortex. After analyses of idealized models of the cortex, I offer a mechanism for the response differences between Simple and Complex cells within the framework of a large-scale neuronal network model, which is based upon the cortical anatomy and physiology of the macaque primary visual cortex. My results suggest that the Simple-Complex classification reflects different synaptic balances and drives

within the same basic model circuit. Since the dichotomy of "Simple" and "Complex" behavior is seen in other areas of cortical processing, the basic explanation may be widely applicable.

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### MS107

### How Hot is Hot? Modeling, Measurement and the Role of Partition Placement

A popular method of encoding chaotic time-series from a physical experiment is the "threshold crossings technique, relative to an arbitrary partition. The intent of symbol dynamics is to describe a dynamical system, but only a generating partition is expected to uniquely encode trajectories. We rigorously investigate some consequences of using itineraries relative to a nongenerating partition. We find the misrepresentation can be severe, including diminished topological entropy (but devil's staircase-like and surprisingly nonmonotone), and a high degree of nonuniqueness.

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### MS107

### A Dynamical Systems Approach to Signal Theory

Chaotic systems can be viewed as natural sources of informationbearing waveforms. By converting the waveform to discrete time (usually via Poincar sampling) and to a discrete alphabet (via a generating partition on the Poincar surface), the information contained in the waveform is reduced to a sequence of symbols from a finite alphabet. A simple example of this viewpoint is the Lorenz system, where the symbols are from a binary alphabet, and the ones and zeros can be associated with the negative and positive peaks in the waveforms respectively. By controlling the statespace trajectory of the system with small perturbations, the symbolic output can also be controlled to any desired sequence. In this viewpoint, the waveform source model is a dynamical system. The classical theory of information transmission, however, takes an entirely different approach. The symbols are encoded into the continuous-time waveform by associating them with basis waveforms, and the sum of all the basis waveforms produces the informationbearing signal. The simplest example of this is the classical pulse train, where the ones and zeros determine the polarity of a fixed timelocalized pulse shape and a sequence of these pulses of alternating polarity carries the information. In this talk, I will present a resolution of this dichotomy, whereby chaotic dynamics topologically equivalent to an idealized Lorenz system is produced by a sequence of pulses using random polarity linear superposition. Quantitative dynamicalsystems measures such as entropy, Lyapunov exponents, and dimension will be shown to be related to the properties of the pulse shape.

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### MS107

### Symbolic Analysis of Scalar Time-Series

A short, noisy time-series can be analysed as a symbolic sequence given a good partition of state space for assigning the symbols. A tesselated partition is constructed from the time-series that minimizes the discrepency between time-series and symbolic sequence. The symbolic sequence is then modelled using context trees. It is shown that this approach yields models with metric and topological entropies that agree well with actual values for some test systems.

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### MS107

### Estimating Good Discrete Partitions from Observed Data: Symbolic False Nearest Neighbors

A symbolic analysis of observed time series data typically requires making a discrete partition of a continuous state space containing observations of the dynamics. A particular kind of partition, called "generating", preserves all dynamical information of a deterministic map in the symbolic representation, but such partitions are not obvious beyond one dimension, and existing methods to find them require significant knowledge of the dynamical evolution operator or the spectrum of unstable periodic orbits. We introduce a statistic and algorithm to refine empirical partitions for symbolic state reconstruction. This method optimizes an essential property of a generating partition: avoiding topological degeneracies. It requires only the observed time series and is sensible even in the presence of noise when no truly generating partition is possible. Because of its resemblance to a geometrical statistic frequently used for reconstructing valid time-delay embeddings, we call the al-

gorithm "symbolic false nearest neighbors".

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## MS107
### Symbolic Dynamics via Algebraic Topology

One of the simplest ways in which chaotic systems can be characterized is through symbolic dynamics. An obvious difficulty in determining the symbolic dynamics of an experimental or numerically generated time series is that the data contains both the chaotic dynamics of the underlying deterministic system and the random fluctuations produced by stochastic perturbations associated with the experimental process or the numerical errors. In this talk an approach (developed jointly with M. Mrozek, A. Szymczak, and J. Reiss) based on topological techniques will be described. An important point is that under the assumption that the noise is bounded one can rigorously reconstruct the symbolic dynamics of the deterministic system. Examples indicating how this technique can be applied in practice will be provided.

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## MS107
### Information Flow in Chaos Synchronization

We use symbolic dynamics to examine the flow of information in unidirectionally coupled chaotic oscillators exhibiting synchronization. The symbolic description of chaos synchronization dramatically illustrates the high degree of information redundancy employed by continuous coupling. This redundancy leads one to expect synchronization to be resistant to noise and distortion, but this is not always observed in practice. We show that this inconsistency is due to inefficient use of the channel capacity, and we present experimental results showing high-quality synchronization using a minimal-capacity channel: two electronic oscillators are synchronized by transmitting only one-bit of information per cycle of the chaotic waveform. Furthermore, we explore so-called achronal synchronization, in which the response lags or leads the drive by a fixed amount of time. We find fundamental tradeoffs between the accuracy to which the drive state is detected, the quality of synchronization attained, and the delay or anticipation exhibited by the response system.

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## MS108
### Impact of Dynamical Generation Models on Power System Stability

Generation of power is critical to the stability of an electric power network. Therefore we must have sufficient detail of the specified generator model such that important characteristics of network events are revealed during dynamical analysis of the network itself. This talk offers a dynamical analysis of generator models found in the literature. The work addresses the effects of features such as power saturation and voltage excitation on stability of the network dynamics.

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## MS108
### Dynamical Modeling and Analysis of Electric Power Networks

Electric power generation and distribution systems are typical examples of technological complex systems with an underlying network structure. Recent advances in the theory of voltage collapse have shown how the dynamical effects of control systems are crucial to an understanding of the collapse phenomena, so that dynamical models and analytic methods are needed. The interactions of these detailed dynamical effects due to the network structure leads to rich dynamics that can exhibit large excursions due to small inputs and other phenomena typical of complex systems.

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## MS108
### Vulnerability Analysis of Complex Networks

This paper considers the problem of determining deep, quantitative information about a complex network using only shallow, qualitative observations concerning network behavior. The complex networks of interest are complicated dynamical systems which result from an evolutionary design process. The desired (deep) information then has a natural interpretation as a subset of the system state, and our focus is on obtaining this information using only metadata, that is, using only limited observations of properties of the underlying system state. Interestingly, our work suggests that the fundamental nature of the complex networks of interest actually increases the information content of the metadata, so that considerable information can be obtained using only limited observations. In this paper we present a formulation of the metadata analysis problem which is both intuitively appealing and mathematically clean, and then describe some of the early results we have obtained through the use of this framework. The efficacy of the proposed approach to metadata analysis is demonstrated through the analysis of several simple examples and one comprehensive case study: the metadata analysis of large, complex social networks.

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**MS108**

**Modeling and Analysis of Computer Networks**

In this talk we discuss models of queue dynamics for multiple access computer networks, like CSMA/CD or CSMA/CA. Our modeling is similar in spirit to approaches found in the IEEE literature, but our approach emphasizes certain important features of the problem, like decoupling, dimension reduction, infinite domain aproximation, etc. We discuss an algorithm for computing a stability coefficient which determines whether the queues remain bounded or grow indefinitely.

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**MS108**

**Application of Differential Geometric Control Methods to Network Dynamical Systems**

Control theoretic methods have come into use in recent years for assessing voltage stability and analyzing mechanisms leading to voltage collapse in large power network systems. As an example, assuming a set of affine system control parameters have been identified, local reachability conditions involving Lie brackets of the drift and input functions can be used to identify the significant parameter-state relationships in a power system at a given operating point. In this talk, a numerical algorithm approximating Lie brackets of nonlinear affinely controlled dynamical systems is presented. The algorithm uses finite difference approximations of directional derivatives to recursively calculate brackets of arbitrary order. Accurate approximations are limited to brackets of order up to two or three due to the numerical instabilities of the divided difference calculations. Comparison with some trajectory sensitivity analysis results of the dynamical system will be presented.

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**MS108**

**Consistent Model Hierarchies of Electric Power Networks that Preserve Local Accessibility Properties**

This presentation considers the problem of determining local accessibility for electric power networks by utilizing hierarchical system abstractions. A low-level power system model and its simpler, high-level abstraction are presented where it is shown that local accessibility conclusions for the simpler model are equivalent to those drawn from the more complex model. Implications of this approach are that reachability studies on large-scale power systems can be replaced with analysis of a less complicated equivalent system.

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**MS109**

**A Geometry of Stochastic Systems**

The solution, and in some cases the parameters of dynamical systems can be modeled as stochastic processes. The efficient characterization and numerical resolution of these processes is paramount to the prediction of the behavior of these systems, and hence to their safe operation. Reproducing kernel Hilbert spaces (RKHS) form the natural mathematical setting for the analysis of such processes. The presentation will review these spaces with an emphasis on their role in characterizing the behavior and performance of stochastic dynamical systems.

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**MS109**

**Error Distribution Models for Strong Shock Interactions**

A key problem in developing methods to quantify uncertainty in a numerical simulation is to understand the dynamic propagation and generation of solution error in a complex flow. For a given numerical method, the solution error for a specific realization can be regarded as the solution to a model equation obtained by the addition of the appropriate higher order diffusion and dispersion terms to the original set of PDE's being solved numerically. Since this model equation depends on the specific numerical method as well as the basic physical flow equations the utility of this abstract approach is limited in real problems, especially for complex nonlinear systems and complex numerical methods. In this talk we will discuss an alternative approach that attempts to build empirical models for error generation based on a stochastic analysis of wave interactions. For simplicity we will focus our attention on describing the probability distribution of error generated due to the interaction of two shock waves. The basic method is an extension to stochastic flows of the fundamental random choice numerical method. Briefly we seek to determine the probability distribution for solution error as a function of the probability distribution for the Riemann problem data. We model this error using a linear super-position of a deterministic component and a random component, where by deterministic we mean a pdf that is a deterministic function of the pdf of the data. The random component is then a function of the numerical method and is modeled as an independent Gaussian. This talk will describe the basic approach for performing the stochastic analysis, the evaluation of specified fitting forms for the deterministic component of the solution error, and estimations of the variance of the random, numerical method dependent, component of the solution error.

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### MS109

### A Stochastic Projection Method for Fluid Flow

Many flows are subjected to uncertainties due to poor knowledge or stochastic nature of external forcings, boundary conditions, physical properties or model coefficients. Statistical treatment and adaptated numerical methods are then required. Here, the Stochastic Spectral Method is used to propagate and quantify uncertainty in laminar flows. It is based on orthogonal expansions using Polynomial Chaos basis. Spectral coefficients are determined through Galerkin projection. Its efficiency is shown for some flows involving stochastic boundary conditions.

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### MS109

### Bayesian Estimation of Uncertainty in Dynamical System Modeling

In this talk we present a fully nonlinear Bayesian scheme for accomplishing two goals simultaneously. These are: A) Fitting parameterized dynamical system models to sequential observations, and B) Estimating magnitude of the irreducible gap between model class and reality, due for instance to unmodeled physics. The theory will be described in abstract, and applied to examples of low dimensional dynamical systems as well as partial differential equations.

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### MS109

### Uncertainty Quantification of Large Computational Engineering Models

A necessary first step in the robust design and optimization of terascale engineering models is the quantification of uncertainty in their response. This uncertainty can arise from a variety of sources including uncertain inputs, uncertain parameters embedded in the models, and/or uncertainty in model form. The presentation will discuss the development of tools to perform the uncertainty assessment in a massively parallel, multiphysics computational environment and the results of the application of such tools to a large-scale engineering analysis problem.

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### MS110

### Periodic Motion for Coaxial Vortex Ring Configurations

We prove a new extension of the Poincaré-Birkhoff to nearly integrable finite-dimensional Hamiltonian dynamical systems having two or more degrees of freedom. This extension is then used to generalize a recent result of Blackmore and Knio on vortex ring dynamics. In particular, the following is proved: If in a configuration of $n$ coaxial vortex rings, with strengths of the same sign, moving in a perfect fluid, the rings are initially sufficiently close together, then there exist (relative to a certain moving coordinate system) periodic orbits and invariant KAM tori.

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### MS110

### Vortex Sheet Simulations

Difficulties arise in simulating vortex sheet motion due to Kelvin-Helmholtz instability, Moore singularity formation, and spiral roll-up. The vortex-blob method has been used to regularize the problem, although high precision arithmetic may be required to maintain accuracy. The regularized solutions display features of a chaotic Hamiltonian system. Treecode algorithms are being developed to reduce the computational expense. This talk will review recent simulation results obtained in collaboration with Keith Lindsay (NCAR), Monika Nitsche (University of New Mexico), David Bailey and Xiaoye Li (NERSC/LBNL).

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### MS110

### Monte-Carlo Simulations and the Physics of 2D Vorticity

Ginibre derived an exact expression for the statistical equilibrium point vortex gas partition function in the standard limit at one value of the inverse temperature. His method was based on the Wigner-Dyson model of the statistics of the spectra of random matrices. One of the remarkable results of this work is the Ginibre scaling: The equilibrium distribution of a point vortex gas of $N$ particles in the canonical ensemble at a inverse temeprature $\beta = 2$ and chemical potential $\mu = 1$ has the form of a nearly uniform disk $\Omega_N$ of radius $R \sim \sqrt{N}$ and exponentially decaying particle densities outside $\Omega_N$. The first aim of this paper is to numerically verify the Ginibre scaling for a wide range of values of $\beta$ and chemical potential $\mu$ and to study the

effects on the particle distribution function of changes in $\beta$ and $\mu$. We find that the Ginibre scaling $R \sim \sqrt{N}$ holds for all values of positive $\beta$ and $\mu$. Our results justify the role of the Ginibre scaling in the applications of vortex statistics to coding theory and numerical quadrature.

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### MS110

### A Statistical Equilibrium Theory of Axisymmetric Flows with Application to the Vortex ring pinch-off process

The statistical equilibrium theories of Miller, Weichman, and Cross [Phys. Rev. A 45, 2328 (1992)] and Robert and Sommeria [J. Fluid Mech., 229 (1991) for two-dimensional flows in Cartesian coordinates are extended to axisymmetric flows. The final equilibrium state satisfies a variational principle similar to Kelvin's variational principle. This theory motivates modeling of the vortex ring pinch-off process. Direct numerical simulations of the vortex ring pinch-off process will be presented and the validity of some of the assumptions will be examined.

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### MS110

### The Spherical Model of Logarithmic Potentials As Examined by Monte Carlo Methods

Monte Carlo methods are used to investigate extremal configurations of logarithmic potentials (representing point vortices) with system circulation and enstrophy constrained to a single value and energy canonically constrained by an inverse temperature parameter. By studying how the organization of a system depends on the number of points in the Monte Carlo simulation it becomes possible to draw conclusions regarding the analytic properties of this system, and to argue for the existence of a single phase transition, as inverse temperature changes from negative to positive values.

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### MS110

### The Statistical Mechanics of Ideal Fluid and Magneto-Fluid Turbulence

Not available at time of publication.

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### MS110

### Theoretical and Numerical Issues Related to Vorticity and Energy Fluxes in 2D and QG Turbulence

Due to its mathematical tractability, two-dimensional (2D) fluid equations are often used by mathematicians as a model for quasi-geostrophic (QG) turbulence in the atmosphere, using Charney's 1971 paper as justification. Superficially, 2D and QG turbulence both satisfy the twin conservation of energy and enstrophy, and are unlike 3D flows, which do not conserve enstrophy. Yet 2D turbulence differs from QG turbulence in fundamental ways, which are not generally known. Here we discuss ingredients missing in 2D turbulence formulations of large-scale atmospheric turbulence. We argue that there is no proof that energy cannot cascade downscale in QG turbulence. Indeed, observational evidence supports a downscale flux of both energy and enstrophy in the mesoscales. We then propose a solution to a puzzle in atmospheric energy spectrum, which remained unsolved in over 30 years.

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### MS111

### A Lagrangian Stochastic Model for Dispersion in Unsteady Inhomogeneous Sub-filter Scale Turbulence

In many applications from the fluid dynamics laboratory to oceanographic flows, computer modeling or observational data typically results in a discretized velocity field. The knowledge we have of the flow under study is limited by the spacing between grid points in space and time. In a laminar flow, this limited knowledge may be adequate to sufficiently describe how particles are advected through this flow. But, in a turbulent flow, we need a way to determine the effect of the sub-grid or more generally, sub-filter scale, below which structure is not resolve, on particle advection. Many attempts in oceanographic and other fields have been made to model the unresolved Lagrangian dynamics as an Ornstein-Uhlenbeck process by assuming homogeneity and stationarity of the velocity statistics at the sub-grid scale. We overcome this limitation through the employment of a more sophisticated Lagrangian stochastic (LS) model capable of capturing inhomogeneous and unsteady effects. This LS model is used to investigate the relationship between small-scale turbulent dispersion and Lagrangian coherent structures in a quasigeostrophic double-gyre model and in HF radar velocity data of Monterey Bay. The existence of coherent structures mandates the use of a LS model which adapts to temporal and spatial variations in the prescribed flow.

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### MS111

### Strange Eigenmodes in Diffusive Mixing

We discuss the existence of asymptotic spatial patterns for diffusive tracers advected by a general two-dimensional ve-

locity field. The asymptotic patterns arise from convergence to a time-dependent inertial manifold in the governing advection-diffusion equation. For time-periodic velocity fields, the inertial manifold is spanned by a finite number of Floquet solutions, the "strange eigenmodes" observed first by R. Pierrehumbert in numerical studies of diffusive tracer advection. Our results indicate that in the limit of vanishing diffusivity, the support of the strange eigenmodes shrinks to unstable periodic orbits of the velocity field.

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### MS111

### Lagrangian Transport and its Implications for Ocean Modeling

Much data in the ocean is Lagrangian in that it is derived from subsurface floats or surface drifters following the flow. At the same time, many questions about the ocean involve transport and mixing, and therefore raise Lagrangian issues. Advances in the use of dynamical systems ideas have afforded a deeper understanding of Lagrangian transport. A striking application that significantly elucidates cholorophyll dispersion in the Gulf of Mexico will be presented. A general strategy for model analysis, based on this theory, at both model input and output, will also be described. This will include Lagrangian data assimilation, optimal float placement design and a new approach to model evaluation.

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### MS111

### Lagrangian Coherent Structures in High-Frequency Radar Data: Open-Boundary Modal Filtering, Hyperbolic Trajectories and Lyapunov Exponents in Monterey Bay

Developments in dynamical systems theory have brought a wide range of methods that can be used to analyze and predict Lagrangian behaviors in geophysical flows. These techniques give detailed information about the location of temperature fronts, the motion of salinity fronts and the distribution of passive drifters. However, they require the ocean to be described as a dynamical system, that is, a fairly smooth differential equation. Increasingly accurate remote sensing techniques are available today and it is both appealing and unavoidable to use the measured velocities directly to describe the dynamical system. We present a practical use of Open-Boundary Modal Analysis (OMA), a complete set of eigenfunctions designed to interpolate, extrapolate and filter flows on an arbitrary domain. The region of interest is a small rectangle along the California coast, centered on Monterey Bay. The boundary is "open", it is not completely closed by a shoreline and an arbitrary flow exists on certain edges of the domain. In this case, which is typical of coastal HF radar data, an proper analysis technique such as OMA is required to obtain the correct flow through the boundary. OMA allows the study of Lagrangian quantities in experimentally measured flow fields with an arbitrary domain. We focuse on hyperbolic trajectories, stable and unstable invariant manifolds, Lyapunov exponents and Lagrangian coherent structures. The existence of finite-time hyperbolic trajectories and finite-time invariant manifolds strongly depends on the structure of the flow field and the corresponding barriers may not be seen if the flow is too complicated. On the other hand, the computation of direct Lyapunov exponents provides less refined pictures of the Lagrangian structure in the flow, but these snapshots of the manifolds are robust and can be computed at any time, no matter how complicated the structure of the flow is. OMA allows progressive levels of complexity in the filtered flow. We compare the Lagrangian structures and invariant manifolds of hyperbolic trajectories for different levels of complexity and the raw, unfiltered data.

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### MS111

### ONR's program in Dynamical Systems and Ocean Modeling

I will describe ONR's interest in ocean and atmospheric modeling, highlight some of its history in the past ten years, and point out its plans for the near future.

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### MS111

### Uncertainty and Predictability in Geophysical Flows: The Role of the Koopman Operator

Dynamical systems that describe geophysical flow situations have complex Eulerian and Lagrangian characteristics due to nonlinearities. The issue of predictability is thus central to the subject. We show how a representation of dynamics on the infinite-dimensional space of observables, achieved through the definition of the so-called Koopman operator (which is adjoint to Perron-Frobenious) allows us to treat these problems in the light of study of spectral properties of the Koopman operator. A model validation procedure based on this is introduced. Uncertainty properties are studied. A new type of decomposition is proposed, named Mixed Orthogonal Decomposition, and its properties discussed in terms of Lagrangian dynamics in oceanographic flows.

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### MS111

### Extracting Structures Out of Closed Chaotic Flows

A method of visualizing structures in closed chaotic flows out of homogenous particle distributions is presented in the example of a geophysical flow. To this end, the system will be leaked or opened up by defining a region of the flow, so that a particle is considered to be escaped if it leaves this region. With applying this method to an ensemble of nonescaped tracers we are able to characterize mixing

processes by visualizing the stretching and converging filamentation in the flow without using additional mathematical tools. A comparison with the finite time manifolds is discussed.

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## PP1

### Distinct Synaptic Pathways Control the Frequency of a Rhythmic Network

The crab gastric mill rhythm shows a high or low cycle frequency depending on synaptic inputs. We have built a model of the gastric mill central pattern generator that receives both modulatory inputs and fast rhythmic inputs from the pyloric network. We show that the gastric cycle frequency is affected by both direct pyloric input to the gastric network and by indirect input that changes the modulatory input from tonic to rhythmic.

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## PP1

### Renormalization and Destruction of Tori in the Standard Nontwist Map: Recent Results

Extending the work of del-Castillo-Negrete, Greene, and Morrison, Physica D **91**, 1 (1996) and **100**, 311 (1997) on the standard nontwist map, the breakup of invariant tori with different winding numbers is studied. The new results are interpreted within the renormalization group framework by constructing renormalization group operators (RGO) on the space of commuting map pairs and by studying the fixed points of the so constructed operators. The relation between RGOs for different winding numbers is studied.

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## PP1

### Determination of Interaction Mechanism from Time Series

The problem of identification of interaction mechanism from time series (measured from interacting systems) is addressed. It is solved with the aid of global reconstuction of model equations from the time series. Namely, the structure-selection technique, which allow to obtain an optimal polynomial model, is used. The model structure achieved with the structure-selection procedure can reveal the mechanism of coupling between investigated systems. The conclusion made is validated by the adequacy of the corresponding model obtained from time series.

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## PP1

### Chaos and Self-Oscillatory Regimes in Ecological Systems

The presented work is a prolongation of a series of investigates dedicated to qualitatively-numerical research of model of dynamics of two and three populations interacting by predator-prey principle. The purpose ofpresent work is to investigate model of dynamics of two competing prey and one predator , taking into account saturation effect in predator populations. We show the existence of chaod and self-oscillatory regimes in system. The investigations has been carried out qualitatively based on the bifurcation theory and also by means of a computer experiment.

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## PP1

### A Canonical Model of Cascades of Mediating Signaling Molecules in Metabolic Cellular Circuits

Dynamical systems derived from mass balance approximations to biochemical reactions of mediating molecules in cellular metabolic pathways are employed to derive canonical models for cascades of signaling molecules. Relative reaction rates lead to a dynamical system with three time scales. Applying singular perturbation techniques to the system yields an analytic approximation of signal molecule concentrations; this enables us to estimate amplification and timing in the cascade.

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## PP1

### Separation of Bioparticles with Multiple-Frequency Traveling Wave Dielectrophoresis

We develop a systems theory of the dielectrophoretic force, which is the force due to the interaction between an electric field and its induced dipole moment in a particle. In this framework, we propose a method of separating T-lymphocytes and red blood cells with multiple-frequency traveling wave dielectrophoresis. The multiple-frequency averaging is performed to investigate the effectiveness of this method.

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## PP1

### Evaluating Causal Relations Among Multiple Nonlinear Time Series

Identifying causal relations among signals is important in multivariate time series analysis. Granger(1969) proposed a simple procedure, referred to as Granger causality, to detect such relations among mutiple linear time series. In this work we generalize Granger's idea to detect causality among nonlinear time series. A simple algorithm is proposed and applied to multiple chaotic time series and other types of nonlinear signals.

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## PP1

### Channeling Behavior in a Polymer Gel Model

Gels can be found in many natural and man-made systems. Gels can be responsible for maintaining physical structure as well as controlling diffusion of chemicals. The polymeric nature of gels changes the stress/strain relationship as well as the flow properties of gels. We analyse the behavior of a pressure driven gel which shows how the non-Newtonian behavior can cause abrupt changes in the gel structure.

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## PP1

### Theory of the Dependence of Dna Configurations on Salt Concentration

A method is presented for calculating the influence of screened electrostatic forces on the equilibrium configurations of intrinsically curved DNA obeying a recently developed theory of sequence-dependent DNA elasticity. Detailed results showing how the minimum energy configuration of a highly curved DNA molecule with a helical axial curve extends (straightens out) as the concentration of monovalent salt decreases from 1 M to 5X10-6 M.

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## PP1

### Pattern Formation in a Network of Excitatory and Inhibitory Cells with Adaptation

A system that describes the temporal evolution of the neuronal activity in the presence of adaptation, for a one-dimensional infinite network with both excitatory and inhibitory interactions, is considered. We construct the normal forms for a Hopf and a double-zero bifurcation with symmetry, and prove that spatial (steady states) and spatio-temporal (traveling and standing waves) patterns can bifurcate from the trivial solution. Numerical simulation results are also obtained.

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## PP1

### Front Dynamics in Reaction-Diffusion Systems with Fractional Diffusion

The validity of reaction-diffusion models rests on the assumption of Gaussian diffusion. However, many studies have pointed out the prevalence of non-Gaussian diffusion. Motivated by this, we study front dynamics in the Fisher-Kolmogorov equation with a fractional diffusion operator. Numerical and analytical results show that anomalous diffusion leads to an exponential front speed, and a universal power law decay of the front. These results are relevant to systems where anomalous diffusion is due to Levy flights.

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## PP1

### A Fractal Model of the Big Bang

The Mandelbrot Set, discovered by Benoit Mandelbrot in the 1980s, as publicized in his book THE FRACTAL GEOMETRY OF NATURE, has heretofore escaped interpretation. We would like to propose how a quaternionic Mandelbrot set might serve to explain the big bang theory of cosmology. We do this by first making a linear transformation from the quaternions to the Minkowski space-time continuum that will preserve its metric. We proceed to examine how to contruct a quaternionic Mandelbrot Set. We then examine the relationship between a Mandelbrot Set and its associated Julia Sets. We finish our discussion by proposing how the associated Julia Sets of a quaternionic Mandelbrot Set would serve to model the big bang. By parametrizing its coordinates to be in accord with known values for the speed of light, c, and the gravitational constant, G, we would be able to predict under what conditions stellar formation occurs. A proper understanding of this model would open new avenues of investigation in fusion research.

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## PP1

### Neural Oscillations in the Brain: Methods of Analysis and Functions

Prominent oscillations are observed in many parts of the brain. Examples include the delta rhythm (1-3 Hz), the theta rhythm (3-8 Hz), the alpha rhythm (8-15 Hz), the beta rhythm (15-30 Hz), and the gamma rhythm (30-100Hz). These oscillations have been given different functional roles and have many proposed generation mechanisms. In this work we focus on the beta range oscillation in the cerebral cortex in the monkey performing a visuomotor experiment. Methods of analysis will be one of the main emphases. Our result suggests that these oscillations participate in the mediation of attentional control and can reveal competition among parallel task demands.

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## PP1

### Fast, High-Quality, Numerical Shadowing

For a typical noisy trajectory of a chaotic, dynamical system, there may exist a true trajectory, corresponding to a slightly different initial condition, that shadows it. For finding such shadowing trajectories, a synchronization-based method is presented whose complexity increases only as the number of non-negative Lyapunov exponents, rather than the total system dimension, thus making it fast for many high-dimensional problems. Numerical results are presented corresponding to several chaotic, dynamical systems.

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## PP1

### Analytical Search for Bifurcation Surfaces in Parameter Space

We extend the method of resultants to the computation of bifurcations of steady states in maps and ODE systems. In comparison to numerical methods our approach yields a testfunction that can often be solved analytically. In contrast to analytical techniques based on eigenvalue computation, our method is applicable for systems of intermediate size ($N < 10$). The method is particularly suitable for the detection of Hopf bifurcations and related situations, some of which are of higher codimension. Examples from different disciplines of science are presented.

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## PP1

### Existence and Stability of Localized Pulses in Neural Networks

We consider the existence and the stability of standing pulse solutions of an integro-differential equation used to describe the activity of neuronal networks. The network consists of a single-layer of neurons with non-saturating piecewise linear gain function, synaptically coupled by lateral inhibition. The existence condition for pulses can be reduced to the solution of an algebraic system and using this condition we map out the shape of the pulses for different weight kernels and gains. We also find conditions for the existence of pulse with a 'dimple' on top and for a double-pulse. For a fixed gain and connectivity, we find two single-pulse solutions–a "large" one and a "small" one. We derive conditions to show that the large one is stable and the small one is unstable. Using the same conditions, we also show that the dimple-pulse is stable. More importantly, the large single-pulse and the dimple-pulse are bistable with the all-off state. This bistable localized activity may have strong implications for the mechanism underlying of working memory.

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## PP1

### Cross-over Behaviour in a Communication Network

We consider message transfer in a network which links nodes and hubs. The average travel time between source and target nodes separated by a fixed distance shows fat fractal behaviour as a function of hub density. The introduction of assortative connections between hubs induces a cross-over to power-law behaviour. The spread of infection on this network also shows cross-over behaviour. Our results are relevant for understanding the role of network topology in information spread processes.

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**PP1**

### Transport Rates for Asteroids and Molecules

The analysis of the dynamics of small bodies in the Solar System is typically based on a comparatively small number of rather long single trajectories. In contrast to this we use a set oriented statistical approach for the computation of transport rates in dynamical systems. The methods are not just applied to scattered Kuiper belt objects by a concatenation of appropriate 4-body problems but also to the identification of conformations for molecules.

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**PP1**

### Chaotic Scattering on 1-D Dynamics and Chaotic Scattering Under Attraction Basin Crises

We present results concerning chaotic scattering and one-dimensional maps. For the Modified Bernoulli Shift,we present several estimates for the short and long lifetimes asymptotically exact. Our estimates relate that numbers with the Lyapunov exponent of the Bernoulli Shift. Besides, we found that the lifetime inside scattering center (as a function of the impact parameter) has a complex behavior similar to the already found in the literature (fractal-like or self-similar). For the Modified Logistic Map, we present the role of the attraction basin crises in the lifetime. We show that this crises may causes abrupt transitions on the transient time as a function of the impact parameter (for the same beam energy).

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**PP1**

### Construction of the Simplest Model to Explain Complex Receptor Activation Kinetics

We study solutions to the kinetic equations arising from various simple ligand-reactor models. Focusing on the prediction of the various models for the activity *vs* concentration curve, we find that it is solutions to the kinetic equations arising from the so called dimer model that exibit features observed in some experiments, most noticably a distinct maximum in the activity curve.

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**PP1**

### Phase Locking in an Integrate-and-fire Neuron Model with Interspike Interval Threshold Modulation and Refractory Periods

It is known that phase locking can entrain frequency information for periodic inputs to the leaky integrate-and-fire (IF) model of a neuron. We show that this is still the case when the IF model is made more biologically realistic. We incorporate into our model spike dependent threshold modulation and refractory periods. Firing times from this model define a map on the annulus. We show that a unique rotation number still exists for this annulus map.

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**PP1**

### Localised Solutions in Magnetoconvection

Localised solutions, with only one convection roll, have been observed in two-dimensional numerical simulations of thermal convection with an imposed magnetic field. A simple model is considered to help understand their formation. This model is compared to others that may be derived on symmetry grounds, forming a coupled cell system, or by performing a boundary layer analysis. Preliminary numerical results in three-dimensions also show localised structures.

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**PP1**

### Discrete Time Model of Bark Beetle Infestations and Epidemic Waves

A discrete time model to approximate the spatial and temporal dynamics of Mountain Pine Beetle outbreaks is presented. The model is constructed using a simple approximation to the growth of the trees coupled with the nonlinear redistribution of the beetle population and transmission model which incorporates the Allee effect of beetle mass attack. An introduction to the model is given as well as an analysis of the linear stability of the system. The conditions necessary for traveling waves are also examined. Using a 'test function' approach we determine sufficient conditions for successful establishment of a bark

beetle outbreak. In addition, the range of speeds at which epidemic waves propagate is also examined.

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### PP1
### Vanishing Twist in the Hopf Bifurcation

We consider a Hamiltonian system with two degrees of freedom undergoing a Hamiltonian Hopf bifurcation. In the compact case we study the relation between singularities of the Liouville foliation of the integrable normal form and the isoenergetic nondegeneracy condition used in KAM theorems. If this condition is violated for an invariant torus we say that it has vanishing twist. We prove that near the isolated focus-focus singularity of the energy-momentum map of the Hopf bifurcation there is a one parameter family of invariant tori with vanishing twist. This implies that near the unstable equilibrium point in a Hopf bifurcation there are so called meandering invariant tori.

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### PP1
### Coupled Map Lattice Models of Tree Migration

Coupled map lattices with random perturbations are used to model the dynamics of tree migration. Computer Simulations of the models demonstrate that trees can migrate with an acceleration regardless of the existence of a fat-tail distribution in the seed dispersion. Simulations also show that the acceleration in tree migration is due to the local accelerated growth of the tree population and a fat-tail distribution can elongate the acceleration period and thus, makes it easily detectible.

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### PP1
### Complete Replacement of Chaotic Uncertainty with Transmitted Information

Chaotic systems may be controlled with small perturbations to execute orbits yielding a specified symbolic itinerary as long as the grammatical rules of those transitions are allowed by the natural dynamical system. We employ techniques taken from data compression (**source modeling** and **arithmetic coding**) but reverse their usual roles to create a channel coder tuned to the observed natural dynamics. With the model, we encode an arbitrary IID white binary message into an itinerary that matches the natural grammar and measure. We drive the transmitter circuit to this itinerary. The transmitter's orbits are **indistinguishable in grammar and measure from the uncontrolled attractor**, demonstrating chaotic stegeanography with no rate loss. All the information naturally generated from chaos has been replaced by message bits at the same rate. We show experimental results using a controllable electronic circuit and a concrete software implementation for estimating the symbolic dynamics and performing the coding.

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### PP1
### Equilibria by Superposition

When two or more equilibrium configurations have complementary fixed point structures, they can be superposed to create new equilibria. We will show how to 'design' composite equilibrium structures this way in the context of point vortex configurations on a sphere. These composite structures are made up of more than one vortex strength and have nonlinear stability/instability properties built in. The method works because the streamfunction- vorticity relation is a linear one, and can be used both for fixed and relative equilibria.

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### PP1
### Oscillatory Marangoni Convection in Binary Mixtures in Square and Nearly Square Containers

Three-dimensional simulations of oscillatory convection in binary mixtures driven by the Marangoni effect have been performed. The upper surface of the fluid is heated by a constant heat flux while the bottom is maintained at a constant temperature. Surface deflection is ignored. Oscillations are the result of concentration-induced changes in the surface tension due to the presence of an anomalous Soret effect. In domains with a square horizontal cross-section and aspect ratio $\Gamma = 1.5$ these take the form of either a standing wave with left-right reflection symmetry or a discrete rotating wave, depending on the separation ratio and the Schmidt number. Standing oscillations with reflection symmetry in a diagonal are unstable. When the cross-section is slightly rectangular only the former bifurcate from the conduction state, and the transition to stable rotating waves with increasing Marangoni number proceeds

via a sequence of secondary local and global bifurcations. The results are interpreted in terms of predictions from equivariant bifurcation theory.

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### PP1

### Modeling of Dynamics of the Plasmodium of True Slime Mold

We have studied pattern dynamics and information processeing of the plasmodium of it Physarum polycephalum, a large amoeboid cell. It exhibits shuttle streaming of endoplasm with the period about 2 minutes, the formation of tubular network and its restructuring. We present a model which includes the coupled oscillators distributed in the ectoplasmic tubes, the endoplasmic flow and the gel-sol transition. It will be discussed how the plasmodium behaves in a well-coordinated manner.

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### PP1

### Dynamics of Multiple Sclerosis (ms)

MS is an autoimmune demyelinating disease of nervous system. Despite its etiological heterogeneity, the overall disease process is similar among patients; relapse-remission phase followed by steady progression of neurological deterioration. Here I propose a model, based on known cellular and cytokine interactions, to simulate inflammatory attack and demyelination in the brain tissue. The model exhibits a bistability through saddle-node bifurcations, which may underlie the transition from relapse-remission phase to secondary progressive stage of this disease.

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### PP1

### Control of Integrable Hamiltonian Systems

We consider the generic properties of control schemes for integrable hamiltonian systems. The controller targets an exact solution of the system in a region where the open-loop dynamics has invariant tori. The phase of the control gain determines whether the control is conservative or dissipative. We show that, in the limit of a purely dissipative controller, a Takens-Bogdanov bifurcation can occur which implies extreme noise sensitivity. We motivate our results using a driven nonlinear Schrodinger equation.

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### PP1

### A Two-Variable Model of Somatic-Dendritic Interactions in a Bursting Neuron

We present a two-variable delay-differential-equation model of a pyramidal cell from a weakly electric fish that is capable of "ghostbursting" discharge. We have modeled the effects of back-propagating action potentials by a delay, and use an integrate-and-fire mechanism for action potential generation. The simplicity of the model allows us to derive a map for successive interspike intervals, and to analytically investigate the effects of time-dependent forcing on such a model.

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### PP1

### A Discrete Theory of Connections on Principal Bundles

Motivated by applications to Discrete Lagrangian Reduction, we consider the discrete analogue of the Atiyah sequence of a principal bundle, and relate a splitting of the discrete Atiyah sequence with discrete horizontal lifts and discrete connection forms. Continuous connections can be obtained by taking the limit of discrete connections in a natural way. This yields an isomorphism between $(Q \times Q)/G$ and $\tilde{G} \oplus (S \times S)$. Both the discrete connection and the associated continuous connection are necessary to express the Discrete Lagrange-Poincare operator in coordinates.

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### PP1

### Global Attractivity of Nash Equilibria of a Labor-Managed Oligopoly

Abstract: We consider the dynamic model of a labor-managed oligopoly in the form of a system of differential equations. Under natural conditions this system has Nash equilibria which are stable and globally attractive.

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**PP1**

### Symbolic Dynamics for Homoclinic Tangles with Asymmetric Perturbations

The behavior of homoclinic tangles of 1.5 d.o.f. systems is studied geometrically, using the asymmetrically forced, damped Duffing oscillator as a prototype model for systems with asymmetric perturbations. Symbolic dynamics is constructed of segments of the unstable manifold, using the geometrical interpretation of the homoclinic bifurcation points. This provides an approximation for the initial development of the homoclinic tangle. Two sided and one sided homoclinic tangles are discussed and compared.

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**PP1**

### Propagation and Immunization of Infection on General Networks with Both Homogenous and Heterogeneous Components

We consider the entire spectrum of architectures of general networks, ranging from being heterogeneous (scale-free) to homogeneous (random), and investigate the infection dynamics by using a three-state epidemiological model that does not involve the mechanism of self-recovery. This model is relevant to realistic situations such as the propagation of a flu virus or information over a social network.We have also considered the problem of immunization for preventing wide spread of infection, with the result that targeted immunization is effective for heterogeneous networks.

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**PP1**

### Time-Periodic Solutions of the Complex Ginzburg-Landau Equation

We report on a project to find time-periodic solutions, up to a space translation and rotation of the amplitude, to the 1D complex Ginzburg-Landau equation with periodic boundary conditions. The solutions found include new periodic solutions with broad temporal and spatial spectra. The computations use truncated Fourier expansions and numerical solution of the resulting systems of nonlinear algebraic equations.

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**PP1**

### Time-Optimal Control of the Dynamic System of a 2-D Rigid Cylinder and a Point Vortex

This paper studies the motion and control of a two-dimensional rigid cylinder dynamically interacting with a point vortex in an incompressible, inviscid fluid. First, the equations of motion for the system with an external force on the cylinder will be explored. Then, time-optimal control theories are applied to find the control force, subject to a kinetic energy constraint, for optimal trajectories of the body between two points in the fluid.

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**PP1**

### Associative Memory Based on a Symmetric-Global Coupled Map Architecture with Feedback

In this work we take a network that consists of a lattice of chaotic couple elements and introduce a small feedback schema to obtain a powerfull architecrure for an artificial neural network. Our proposed architecture can be efficiently used to store and manipulate information, so that it can be used as a dynamical associative memory. Our architecture is an evolution of the S-GCM model and is also based on a bi-stable symatric map that implies a large area of "cluster frozen attractors" in the pase space, which can be exploited to represent information. In addition, we show that with the introduction of another feedback loop, this network presents an "annealing"-like capability that can be used to solve a hard classe of optimization problems. To show up this capability, we use it to solve the classical TSP problem, which is defined as the task of the salesman visiting all cities in a list once and once only, and returning to his starting point with the minnimum cost. This is a classical combinatorial optimization problem where the minimization of a cost or energy function has to be carried out.

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**PP1**

### Synchronization in Nonhyperbolic Hyperchaotic Systems

We propose a methodology to address the outstanding problem of synchronization in nonhyperbolic hyperchaotic physical systems. Our approach makes use of a controlling of chaos strategy that accomplishes the taks by transmitting only one scalar signal even in the presence of noise.

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## PP1

### Normal Forms for Non-Linear Systems of High Codimension with Nilpotent Linear Part

The set of systems that are in normal form has the structure of a module of equivariants and is best described by giving the stanley decomposition of that module. The groebner bases methods (implementable in computer algebra systems) is used to determine the Stanley decomposition of the ring of invariants, that arise in normal forms for systems with Nilpotent linear part, consisting of repeated 2x2 Jordan blocks. Then an efficient method developed my James Murdock is used to produce the Stanley decomposition of the module of equivariants from the stanley decopmposition of the ring of invariants.

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## PP1

### Existence and Stability of N-Pulses in Optical Fibers with Periodic Phase-Sensitive Amplifiers.

Dark solitons are the steady solutions of Schrödinger equation with normal dispersion. To control dark solitons in optical communication system A.D. Kim, W.L. Kath, C.G. Goedde proposed periodically spaced phase-sensitive amplifiers. As a result of multiscale averaging the evolution equation derived by them, is 4th order partial differential equation. Using dynamical systems methods existence and stability of multi-pulses of the 4th order PDE will be discussed. Stable multi-pulses are found.

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## PP1

### Dynamic Modeling of Free-Running Hamster Circadian Rhythms

We exposed hamsters to a short bright light on the tenth day of twenty four days of continuous recording. We measured three outputs of the circadian rhythm generator: wheel running: core temperature; gross motor activity. We used three dynamical systems to represent the circadian rhythm, and nonlinear transforms of the dynamical systems to model the observed behaviors. We illustrate the modelling, the transformed output, and the representations of the effects of the light pulse.

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## PP1

### Weakly-Nonlinear Behavior of Non-Newtonian Instabilities in Core-Annular Flow

Viscoelastic fluids experience many instabilities even in zero Reynolds number flow. It has been shown experimentally and analytically that the presence of elastic differences across an interface can cause instabilities even when other properties are constant. Such interfaces occur in many industrial applications, e.g., the production of composite materials. We study the weakly-nonlinear growth of the instability in the planar analogue of core-annular flow and investigate the behavior and complications arising in a cylindrical geometry.

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## PP1

### Model-Based Experimental Design for Quantification of Geochemical and Microbial Immobilization of Uranium and Arsenic in Groundwater Systems

A geochemical reaction-path-model was modified to include kinetics such as microbial sulfate reduction. Using literature data, a model-based sensitivity analysis was performed. The results provided the initial range of experimental milieu conditions, e.g. pH, ferrous iron, dissolved organic, and inorganic carbon concentration. Experimental data were, in turn, used as input parameters for the model, improving modelling results. This iteration had been repeated until an optimal identification and quantification of process parameters was reached.

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## PP1

### Cellular Computation by Adaptive Changes in Body Shape of An Amoeba-Like Organism

We report here how to change in body shape of a giant amoeba-like organism of true slime mold. When many food-sources were placed at many locations, the organism extends like a network of tubular elements to reach every food-source. Since this network shape is similar to the shortest connection route, discussion is made on how to solve the problem of path finding in terms of dynamical process of amoeboid movement.

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## PP1

### Presentaion of The 5 Cardiac Sites Web For Modelling And Simuling The Model Pacemakervi1 and The Cardiac Simulator.

Balth an Der Pol is first to propose one Cardiac Simulator in 1928.I eneregister patent about FM Solar Oscillator in 1994 and I find Balth.I dream to invente one Electromechanic Cardiac Simulator and One Electronic cardiac simulator named The Cardiorythmor and to propose one Mathematical Model of the Heart in ODE and one unic model of all the Cardiac Cells named The Model PacemakerVI1 in ODE.I create 5 Sites Web in yahoo to schow figures of simulation:1)http://cf.geocities.com/cardiacsimulator2002/
http://cf.geocities.com/cardiorythmor2002/
http://cf.geocities.com/cardiorythmeur2002/
http://cf.geocities.com/artificialheartVI1/
http://cf.geocities.com/modelpacemakerVI1/

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## PP1

### Phase Oscillator Neural Networks with Error-Free Memory Recall

Inspired by the discovery of possible roles of synchronization in the brain function, networks of coupled phase oscillators has been proposed as models of associative memory based on the concept of temporal coding of information. However, the error-free retrieval states of such networks turn out to be *unstable* regardless of the network size, in contrast to the classical Hopfield model. We propose a remedy for this undesirable property, and provide a systematic study of the improved model.

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## PP1

### Reduction of Interacting-Front Dynamics in Nonlinear Delayed-Feedback Systems

A scalar nonlinear delay-differential equation with external forcing arising in optically bistable systems is reduced, near a Hopf bifurcation, and for a large delay, to a partial differential equation using the multiple scale method. The dynamics of kink defects in the PDE is then reduced to a set of ordinary differential equations using the matched asymptotic expansion principle. This twofold reduction greatly eases the analytical research of multiple-interacting-defect solutions and their stability.

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## PP1

### Explicit Formulae for Stability of Oscillations.

This paper presents linearization of an oscillator that leads to a periodic second order ODE's. Explicit closed-form expression of a fundamental matrix is presented. Its derivation is straightforward, still to authors' knowledge has not been done before. The result is instrumental in the analysis of the original oscillator's frequency stability (phase-noise).

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## PP1

### Invariant Manifolds and Space Mission Design

Recently invariant manifolds have been intensively used in the design of energetically efficient space craft trajectories. If these manifolds are higher dimensional (i.e. ¿ 1) then the question arises which particular trajectory is optimal w.r.t. to control purposes. For instance this applies to the return trajectory of the NASA mission Genesis. Here we present a method based on the computation of expansion rates which allows to detect those optimal orbits.

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## PP1

### Analysis of Super Subdivision of Vonkoch Snow Flake

In this paper, the generation of fractals using Advanced Computer Graphics are discussed. The complete description of Von Koch Snow Flake sets, properites and generation are given in detail. Super subdivision of Von Koch Snow Flake curves are introduced. It is observed that supersubdivison of Von Koch Snow Flake curve is continuous. Also it is observed that in Von Koch Snow Flake curve, a point will be displayed instead of picture if we have DETAILS(side, level) lesser than the pixel diameter.

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## PP1

### A Contact Problem from the Theory of Buckling Rods

We analyze the minimizers of a model functional that describes the energy of a buckled rod constrained to lie on a cylinder. A key question is how to take into account the self-contact behavior as the rod buckles in order to be able to use methods from the Calculus of Variations. We study

the structure of the solutions of this minimization problem, and show that the set of points in which the rod exhibits self-contact is either empty, a single point, or a single interval. Insight is also gained into the structure of contact forces responsible for avoiding self-intersections of the rod.

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## PP1

### A Geometric Analysis of the Lagerstrom Model: Existence of Solutions and Rigorous Asymptotic Expansions

We give a geometric singular perturbation analysis of a classical problem proposed by Lagerstrom to illustrate the ideas involved in the rather intricate asymptotic treatment of low Reynolds number flow. We present a geometric proof based on the blow-up method for the existence and uniqueness of solutions. Moreover, we show how asymptotic expansions for these solutions can be obtained in this framework, thereby establishing a connection to the method of matched asymptotic expansions.

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## PP1

### Heteroclinic Networks in Rotating Convection

Motivated by the problem of pattern formation in rotating thermal convection, we consider two coupled Busse-Heikes cycles that occur when the dynamics are restricted to a hexagonal superlattice. Different types of coupling can lead to heteroclinic networks comprising many heteroclinic cycles. In this case none of the cycles can be asymptotically stable, but they can still be strongly attractive. We investigate conditions for a given cycle to be 'preferred' and examine bifurcations that can occur.

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## PP1

### Stability Analysis of Coupled Neural Systems

Networks of coupled neural systems represent an important class of models in computational neuroscience. In some applications it is required that equilibrium points in these networks remain stable under parameter variations. We present a general methodology to yield explicit constraints on the coupling strengths to ensure the stability of the equilibrium point. Two models of coupled excitatory-inhibitory oscillators are used to illustrate the approach.

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## PP1

### A Measure of Oscillation Frequency for Time-Series, Robust to Arbitrary Linear Filtering

Experimentalists often encounters approximately periodic oscillations of unknown origin in noisy, measured time series. In order to be independent of the signal pathway, characterizations *of the oscillator* generating the signal should be robust to, at least, linear filtering of the signal. Thus, spectral frequency measures fail to be adequate characterizations. A new frequency measure is proposed which can be shown to be robust to arbitrary filtering. Theory and applications in life science are discussed.

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## PP1

### Nontrivial Mappings in the Generalized Synchrony of Chaos.

Generalized synchronization of chaos is characterized by existence of stable persistent functional dependence of response trajectories from the chaotic trajectory of driving oscillator. In many practical cases this function is non-differentiable, multivalued and has a very complex shape. We show that despite these complicating factors in the relation between the current states of the systems, the existence of functional relation becomes apparent when a sufficient interval of driving trajectory is taken into account.

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## PP1

### Convergence of the Gap-Tooth Scheme for Microscopic Simulations in Large Domains

We discuss the numerical convergence of the gap-tooth scheme [I.G. Kevrekidis et al., 2002]. This scheme simulates the evolution of macroscopic variables (moments of distributions) in large domains by running microscopic simulations (Monte Carlo, molecular dynamics) in small boxes (teeth) with appropriate boundary conditions. The boxes are separated by gaps, which implies that an interpolation is needed to give an overall solution. We show the effect of box width and interpolation order on convergence.

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### PP1

### Opening a Closed Hamiltonian Map

The dynamics in Hamiltonian systems has been extensivley investigated in many respects. For example,many researchers have paid much attention on quasiperiodic and chaotic motions in the standard map, which is a closed map. On the other hand,, in open Hamiltonian systems that have escaping orbits, chaotic scattering and exit basins have been thoroughly investigated. One of the simplest examples of such open Hamiltonian systems might be a sctatterer composed of hard disks. So far, in open Hamiltonian systems, there seems to be no simple system corresponding to the standard map as a closed Hamiltonian system. Here we show that a closed Hamiltonian map can be opened by introdcuing an interaction with the outside of the system, in such a way that an exit appears. In the phase space of such a system equipped with two or three exists, the set of initial conditions of the orbits that escape have fractal boundaries and even the Wada property. With the decrease of the sizes of the exits, the fractalization is stronger, and a complete fractalization is observed in the limit of small exits, implying that the predictability of the future is almost lost.

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### PP1

### Application of Nonlinear Time Series Methods to Modeling of a Comlex Biological System (typical Difficulties and Attempts for Their Overcoming)

Existing procedures of parameter estimation from time series are applied to model pressure regulation system in the nephron from experimental time series. We use the model structure proposed by E.Mosekilde etc (it is a system of 6 nonlinear ordinary differential equations which involves 20 parameters) and estimate its parameters from chaotic and periodc scalar times series using multiple shooting algorithm developed by H.G.Bock. We show essential difficulties in application of such a large-size model. To overcome them is sometimes possible, as we illustrate, by 1) using special approaches to search for starting guesses for hidden (unobserved)variables, and 2) simplifying model structure (reparametrization of the model with the purpose to reduce the number of parameters and hidden variables).

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### PP1

### Noisy Pattern Precursors in An Optical System

We study theoretically and experimentally the effects of noise on pattern formation in a liquid crystal subjected to an optical feedback. The noise, that comes from the fluctuations of the liquid crystal director axis orientation, induces below threshold, precursors that anticipate the incoming pattern. Analytical and numerical results performed on stochastic pde are in good agreement with the experimental results in 1D and 2D configurations.

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### PP1

### Complex Behavior in a Plasma Device

The nonlinear and complex behavior of a plasma-filled device is numerically investigated in this work. The system is consisted by two metallic plates separated by a distance L and filled with a background of immobile ions. A electron beam is injected in one of the plates and travels through the system, until one of the metallic plates is reached. Four distinct regimes are observed in the system as a function of its control parameter and the initial conditions. Besides chaotic oscillations, the rich phenomenology and the large diversity of spatio-temporal patterns presented by the system are reported and explored.

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### PP1

### Spike-Time Attractors in Cortical Neurons

The responses of cortical neurons in vitro to fluctuating current injections show stereotyped patterns of spike-time relationships, and similar spike-time istograms occur across neurons with different firing rates, as recently observed in vivo in the cat lateral geniculate nucleus. We analyze spike-time attractors as a mechanism underlying these effects. For time-varying input signals, patterns of spike time outputs are robust against changes in initial conditions and

localized perturbation of voltage trajectories. By systematically varying parameters controlling the shape of the input stimulus we induce bifurcations in spike time patterns, characterized by discontinuous changes in spike times or spike addition/deletion. In the vicinity of spike-time bifurcations the spike-time jitter depends on the noise amplitude in a superlinear manner. The characteristics of the spike time attractor depend on the input stimulus. For example, while a periodic stimulus can lead to multiple attractors (related by a discrete time-shift), a quasi-random aperiodic stimulus will result in a single attractor with multiple converging branches. By comparing computer simulations of integrate-and-fire neurons with in vitro recordings from rat prefrontal cortical neurons driven with identical stimuli, we demonstrate the existence of spike time attractors and show how they allow cortical neurons to fire reliably and precisely in spite of sources of intrinsic variability.

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## PP1

### A Modified Lorenz Model

The Lorenz model introduced to describe certain characteristics of the Rayleigh Bénard problem is revisited. Our main goal being the study of the equivalent mechanical problem of particles interacting through a potential well induced by the system itself. We consider a generalized Lorenz model with six amplitudes in the normal mode expansion, its behavior is analized as a function of the proper dimensionless parameters.

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## PP1

### Chaos, Nonintegrability and Diffusion in Some Hamiltonian Systems with Saddle-Centers

Melnikov-type techniques has recently been developed to analyze homoclinic and heteroclinic behavior for periodic orbits and invariant tori in Hamiltonian systems with saddle-centers and their perturbations. We apply the techniques to study chaos, nonintegrability and diffusions in the Hénon-Heiles system, Euler elastica, and Schrödinger equation in the mean field approximation of a three-quantum-well device problem.

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## PP1

### Integrated Modelling of Aquatic Ecosystem and Contaminants

A simple dynamical model of an aquatic ecosystem with seven state equations describing the dynamics of phytoplankton, zooplankton, bacteria, fish, nutrients in the sediment and in the water column and detritus has been coupled with a contaminant model to study the effects on the attractors, bifurcation points and long term behaviour in species concentration as a function of the physico-chemical properties of the contaminant as well as on its toxicity effects.

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# Speaker Index

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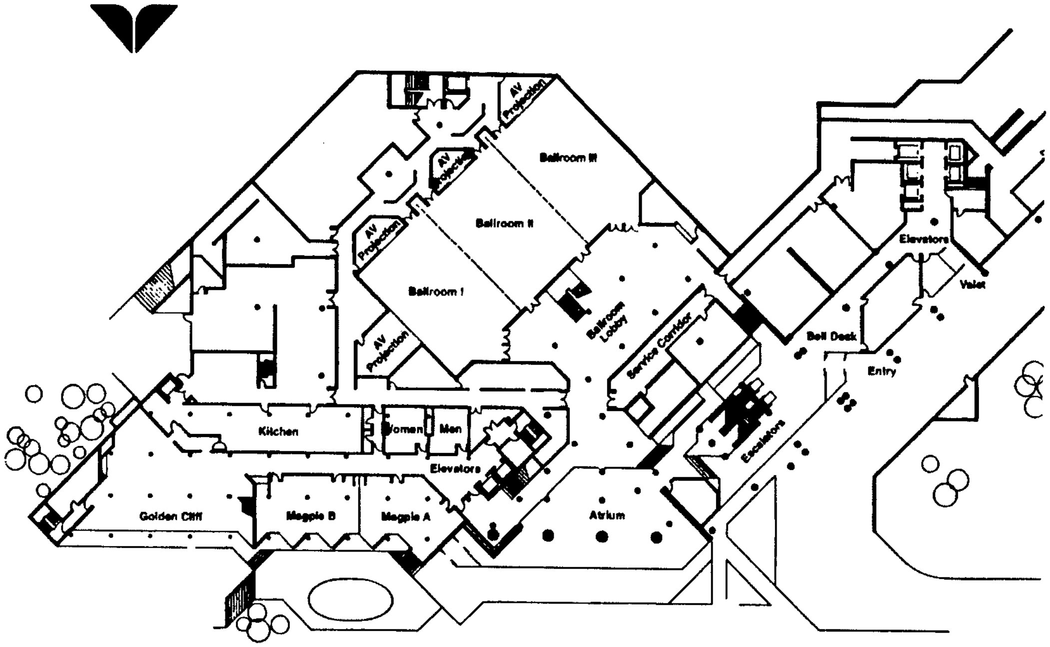



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